Neoparrya lithophila Mathias (Bill's neoparrya): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

November 8, 2004

David G. Anderson
Colorado Natural Heritage Program
8002 Campus Delivery — Colorado State University
Fort Collins, CO 80523

Peer Review Administered by
Center for Plant Conservation

Anderson, D.G. (2004, November 8). *Neoparrya lithophila* Mathias (Bill's neoparrya): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/neoparryalithophila.pdf [date of access].

Acknowledgements

The information in this report draws from the specimens and collection label information resources of the Rocky Mountain Herbarium (RM), the Colorado State Herbarium (CS), the University of Colorado Herbarium (UC), and the University of New Mexico (UNM), plus the information resources compiled and analyzed by Colorado Natural Heritage Program, New Mexico Natural Heritage Program, and Wyoming Natural Diversity Database. David Anderson and Michael Menefee provided the Colorado Natural Heritage Program records; Phil Tonne provided the New Mexico Natural Heritage Program records; Walter Fertig (previously with Wyoming Natural Diversity Database) and Robert Dorn provided the framework and greatly advanced the interpretation of species' status in Wyoming. Maggie Marston (Pawnee National Grassland) and Bill Jennings provided insights into Colorado populations. Robert Dorn and Val Grant provided unpublished information from recent BioResources, Inc. surveys in and adjoining Pawnee National Grassland. Steve Popovich (Arapaho-Roosevelt National Forest), Maggie Marston, Beth Burkhart (USDA Forest Service Rocky Mountain Region), Susan Spackman (Colorado Natural Heritage Program), Richard Spellenberg (New Mexico State University), and Katherine Darrow provided valuable reviews. Funding for the project was provided by the USDA Forest Service Rocky Mountain Region contract 53-82X9-1-137.

Author's Biography

David G. Anderson is a botanist with the Colorado Natural Heritage Program (CNHP). Mr. Anderson's work at CNHP includes inventory and mapping of rare plants throughout Colorado, mapping weeds, maintaining and updating CNHP's database, and writing reports on the rare plants of Colorado. He has worked with CNHP since 1999. Much of Mr. Anderson's prior experience comes from five years of fieldwork studying the flora and ecosystem processes of the Alaskan and Canadian Arctic. Mr. Anderson also served in the Peace Corps as a science teacher in the Solomon Islands from 1996 to 1998. Mr. Anderson received his B.A. in Environmental, Populational, and Organismic Biology from the University of Colorado, Boulder (1991) and his M.S. in Botany from the University of Washington, Seattle (1996).

Cover Photo Credit

Neoparrya lithophila (Bill's neoparrya). Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

Summary of Key Components for Conservation of *Neoparrya lithophila*

Status

Neoparrya lithophila Mathias (Bill's neoparrya) is known from seven counties (Chaffee, Conejos, Fremont, Huerfano, Mineral, Rio Grande, and Saguache) in south-central Colorado. It has also been reported from a yet undisclosed location in north-central New Mexico. It is found primarily on outcrops and cliffs of igneous origin, but it has also been found on limestone substrates. It is currently known from 38 occurrences in Colorado. Based on estimates from some of these element occurrence records, the total population size of *N. lithophila* is between 48,680 and 58,490 plants. However, population size estimates were not made at some occurrences, so this total estimate is low. This species is ranked globally vulnerable (G3) and vulnerable at the state level in Colorado (S3) by NatureServe and the Colorado Natural Heritage Program, respectively. *Neoparrya lithophila* was formerly a sensitive species in Region 2 of the USDA Forest Service (USFS), but it was not included on the sensitive species list signed by the regional forester in 2003. It is included on the Bureau of Land Management Colorado State Sensitive Species List. It is not listed as threatened or endangered under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540).

Primary Threats

Observations and quantitative data have shown that there are several threats to the persistence of *Neoparrya lithophila* in USFS Region 2. In order of decreasing priority these threats are off-road vehicle use, grazing, other recreation activities, mining, timber harvest, effects of small population size, residential and commercial development, right-of-way management, exotic species invasion, global climate change, and pollution. Some threats are more urgent at some sites than at others; thus this hierarchy differs for each site. At many locations, threats to *N. lithophila* resulting from human activities are minor due to the inaccessibility of its habitat and the unsuitability of its habitat for development and grazing. However, off-road vehicle use and grazing have resulted in considerable impacts to some occurrences on USFS land and elsewhere. Activities that concentrate use in occurrences are likely to threaten *N. lithophila*.

Primary Conservation Elements, Management Implications and Considerations

Neoparrya lithophila benefits from some degree of natural protection because its habitat is rugged, largely inaccessible, and unsuitable for development and most forms of resource extraction. Nine of the 38 occurrences are located in areas where they are unlikely to be impacted by some threats such as residential development, road construction, and resource extraction due to protective land status. Pursuing conservation easements, or other protective land status changes, on the private properties where four occurrences are found would help to ensure the viability of occurrences on private land.

Widespread grazing impacts to *Neoparrya lithophila* are unlikely because most of its habitat is inaccessible to cattle and horses. However, it is apparently palatable to cattle, and considerable impacts resulting from livestock grazing have been observed at one occurrence on USFS land. Weeds have invaded limited portions of its habitat but do not appear to be having widespread impacts at present.

Further species inventory work remains a high priority for *Neoparrya lithophila* and is likely to identify other occurrences. Although considerable efforts have been made to find this species, the ruggedness of its habitat makes thorough surveys difficult. Research is needed to investigate the population biology and autecology of *N. lithophila* so that conservation efforts on its behalf can be most effective.

Table of Contents

ACKNOWLEDGEMENTS 2
AUTHOR'S BIOGRAPHY 2
COVER PHOTO CREDIT 2
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *NEOPARRYA LITHOPHILA* 3
Status 3
Primary Threats 3
Primary Conservation Elements, Management Implications and Considerations 3
LIST OF TABLES AND FIGURES 6
INTRODUCTION 7
Goal of Assessment 7
Scope of Assessment 7
Treatment of Uncertainty in Assessment 7
Treatment of this Document as a Web Publication 8
Peer Review of this Document 8
MANAGEMENT STATUS AND NATURAL HISTORY 8
Management Status 8
Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies 8
Adequacy of current laws and regulations 8
Adequacy of current enforcement of laws and regulations 9
Biology and Ecology 9
Classification and description 9
Distribution and abundance 13
Population trend 18
Habitat 18
Reproductive biology and autecology 31
Demography 33
Community ecology 35
CONSERVATION 35
Threats 35
Influence of management activities or natural disturbances on habitat quality and individuals 36
Interaction of the species with exotic species 39
Threats from over-utilization 40
Conservation Status of the Species in Region 2 40
Is distribution or abundance declining in all or part of its range in Region 2? 40
Do habitats vary in their capacity to support this species? 40
Vulnerability due to life history and ecology 40
Evidence of populations in Region 2 at risk 40
Management of the Species in Region 2 41
Implications and potential conservation elements 41
Tools and practices 42
Species and habitat inventory 42
Population monitoring 42
Habitat monitoring 44
Beneficial management actions 44
Seed banking 45
Information Needs 45
Distribution 45
Lifecycle, habitat, and population trend 46
Response to change 46
Metapopulation dynamics 46
Demography 46
Population trend monitoring methods 46

Restoration methods 47
Research priorities for Region 2 47
Additional research and data resources 47
DEFINITIONS 48
REFERENCES 50
EDITOR: Beth Burkhart

List of Tables and Figures

Tables:

Table 1. Summary of occurrences of *Neoparrya lithophila* in areas with protective land status designations..... 8

Table 2. Land ownership status of the 38 known occurrences of *Neoparrya lithophila* in Region 2..... 14

Table 3. Summary information for the 38 known occurrences of *Neoparrya lithophila*. 16

Table 4. Summary of habitat and element occurrence data with management comments noted for the 38 known occurrences of *Neoparrya lithophila*. 19

Table 5. Summary of demographic data from Farisita Dike occurrence of *Neoparrya lithophila* from 1990 through 1992. 32

Table 6. Grazing allotments and current grazing activity for known occurrences of *Neoparrya lithophila* on national forests in USDA Forest Service Region 2..... 38

Figures:

Figure 1. *Neoparrya lithophila* in fruit. 11

Figure 2. Illustration of *Neoparrya lithophila*. 12

Figure 3. *Neoparrya lithophila* in flower. 13

Figure 4. The distribution of *Neoparrya lithophila* in the states of USDA Forest Service Region 2. 14

Figure 5. Known distribution of *Neoparrya lithophila* in Colorado. 15

Figure 6. The distribution of principal geologic strata in relation to the known occurrences of *Neoparrya lithophila*. 27

Figure 7. Wasting slopes of the Dry Union Formation in Chaffee County. 28

Figure 8. Typical habitat of *Neoparrya lithophila* at Farisita Dike. 28

Figure 9. Habitat of *Neoparrya lithophila* at Farisita Dike. 29

Figure 10. An unusual occurrence of *Neoparrya lithophila* on a steep wasting slope, where rapid erosion has left plants standing on pillars of soil. 29

Figure 11. Habitat of *Neoparrya lithophila* at Bear Creek. 30

Figure 12. Close-up photograph of habitat of *Neoparrya lithophila* at Bear Creek on the San Isabel National Forest..... 30

Figure 13. Histogram of change in plant size at Farasita Dike between 1990 and 1992. 33

Figure 14. Hypothetical life cycle graph for *Neoparrya lithophila*. 34

Figure 15. Grazing of *Neoparrya lithophila* at Bear Creek. 36

Figure 16. Impacts to *Neoparrya lithophila* resulting from a road that bisects the occurrence at Methodist Mountain. 37

Figure 17. Damage to individuals and habitat of *Neoparrya lithophila* were observed at Methodist Mountain resulting from high-impact camping..... 38

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Neoparrya lithophila* is the focus of an assessment due to its habitat specificity, high level of endemism, small number of occurrences, and the high degree of isolation of individual occurrences. It was formerly listed as a sensitive species by Region 2 (USDA Forest Service 1993), but it is no longer a sensitive species in Region 2 (USDA Forest Service 2003). It was considered for continuation of its sensitive species status (McKee 2002), but lack of information precluded listing (Patton et al. 2002). It is designated sensitive by the Bureau of Land Management (BLM) (Bureau of Land Management 2000).

This assessment addresses the biology of *Neoparrya lithophila* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological backgrounds upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere, and when these have been implemented, this assessment examines their success.

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Neoparrya lithophila* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *N. lithophila* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

All known refereed and non-refereed publications, reports, and element occurrence records for *Neoparrya lithophila* are referenced in this assessment, and all of the available experts on this species were consulted during its synthesis. All available specimens of *N. lithophila* were viewed to verify occurrences and to incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (Colorado State University Herbarium), RM (Rocky Mountain Herbarium), SJNM (San Juan College Herbarium), CC (Carter Herbarium), Great Sand Dunes National Park Herbarium, GREE (University of Northern Colorado Herbarium), NMCR (New Mexico State University Range Science Herbarium), and UNM (University of New Mexico Herbarium); specimen data available online and in publications and reports were also incorporated. This assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications and reports were used in the assessment when information was unavailable elsewhere. However, these were regarded with greater skepticism than refereed literature. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution of this species, and they contain the vast majority of the useful information known on *N. lithophila*. However, these data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, we must rely on observations, inference, good thinking, and models to guide our understanding of ecological relations.

Confronting uncertainty, then, is not prescriptive. In this assessment, we note the strength of evidence for particular ideas, and we describe alternative explanations where appropriate.

Treatment of this Document as a Web Publication

To facilitate their use in the Species Conservation Project, species assessments are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it will facilitate their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review of this Document

Species assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Neoparrya lithophila is currently not designated a sensitive species in Region 2 of the USFS. Although formerly designated as sensitive by Region 2 (USDA Forest Service Region 2 1993), it was not included on the sensitive species list signed by the regional forester in 2003 (USDA Forest Service Region 2 2003) due to insufficient information and because threats to occurrences on USFS lands appeared minor (Patton et al. 2002). It is listed on the BLM Colorado State Sensitive Species List (Bureau of Land Management 2000). NatureServe considers *N. lithophila* to be globally vulnerable (G3). It is also considered vulnerable (S3) by the Colorado Natural Heritage Program. It is considered vulnerable because it is known from only 38 occurrences, with another 10 to 20 occurrences estimated. Some of the known occurrences are large and naturally protected on somewhat inaccessible rock outcrops (Colorado Natural Heritage Program 2004). For explanations of NatureServe's ranking system, see the Definitions section of this document.

Nine of the 38 known occurrences are found on lands with special protective status (**Table 1**). One occurrence (EO 15) is in the Spring Branch Research Natural Area (RNA) of the Rio Grande National Forest. Current objectives and management prescriptions at this RNA are likely to favor its persistence (Carsey 1996). Six occurrences are found on three areas of critical environmental concern designated by the BLM (Elephant Rocks, San Luis Hills, and Rio Grande River Corridor) where *Neoparrya lithophila* occurrences benefit from current management. The Elephant Rocks occurrence is also included within a Colorado state natural area, where it benefits from voluntary agreements with landowners to protect the unique natural resources of this site (Colorado State Parks 2004). The Farisita Dike Preserve owned by The Nature Conservancy was established to protect *N. lithophila*.

Ten of the 38 known occurrences are located on USFS lands in two national forests: Rio Grande National Forest (six occurrences) and San Isabel National Forest (four occurrences).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Neoparrya lithophila has no legal protection unto itself that would prevent the destruction of individuals or their habitat. As of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other

Table 1. Summary of occurrences of *Neoparrya lithophila* in areas with protective land status designations.

Land Status	Number of Occurrences	Element Occurrence Number
Research Natural Area (USFS)	1	15
Area of Critical Environmental Concern (BLM)	6	8, 10, 19, 20, 21, 24
Preserve (The Nature Conservancy)	1	1
State Natural Area (CNAP)	1	8
TOTAL	**9**	

federal agency. Several occurrences are protected, and many are in somewhat inaccessible sites. *Neoparrya lithophila* is not listed as threatened or endangered in accordance with the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540), through which it would gain considerable protection on federal and state land, and on private land in some cases. There are currently no enforceable laws or regulations that confer any protection to occurrences of this species on private or state lands. On BLM lands in Colorado its sensitive species status requires that *N. lithophila* be considered in management actions to ensure that those actions do not cause the species to require endangered species listing in the future. Ongoing impacts to at least two occurrences of *N. lithophila* on USFS land of the San Isabel National Forest suggest that existing regulations protecting this species on USFS land are inadequate to ensure its protection.

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Neoparrya lithophila* was extirpated due to the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Human impacts such as residential development and grazing may have diminished the abundance of this species.

Enforcement of existing restrictions of off-road vehicle use on USFS and BLM lands is very difficult. Users frequently pull down barriers and breach fences to gain access to off-limits areas (Brekke personal communication 2004). Federal agencies lack sufficient human resources to patrol the vast areas that they manage.

Biology and Ecology

Classification and description

> Parsley
> Is gharsley.
> — Ogden Nash ("Further Reflections on Parsley")

Neoparrya lithophila is a member of the parsley family (Apiaceae). The Apiaceae is composed of 460 genera and 4,250 species worldwide (Zomlefer 1994). It is a cosmopolitan family but more common in the north temperate regions. The Apiaceae family is in the subclass Rosidae, order Apiales (Heywood 1993, USDA Natural Resources Conservation Service 2001). *Neoparrya lithophila* is in the subfamily Apioideae. There is no doubt that *N. lithophila* is a legitimate species, but there is much disagreement among taxonomists regarding its correct generic appellation. Most treatments place it as the only member of the genus *Neoparrya*. Another species (*N. megarrhiza*) has been treated in *Neoparrya* but has been moved to *Lomatium*. Weber (1984) placed *N. lithophila* in the genus *Aletes* (as *A. lithophilus*). However, many authors (Mathias 1929, Theobald et al. 1964, Hartman 1984) contend that it differs in significant ways from other members of *Aletes* and belongs in its own genus. Downie et al. (2002) included *N. lithophila* in a cladistic analysis of the spring-parsleys (*Cymopterus* and its close relatives). This analysis combined nuclear and chloroplast DNA datasets, showing *N. lithophila* to be most closely related to members of *Aletes* (*A. acaulis*, *A. macdougalii* ssp. *breviradiatus*), *Lomatium* (*L. junceum*, *L. latilobum*), and to *Podistera eastwoodiae* and *Pteryxia terebinthina* var. *albiflora*. The authors concluded that existing circumscriptions of genera in this group are highly artificial (not monophyletic), and a complete reassessment of western endemic members of Apiaceae is needed.

As a narrow endemic, *Neoparrya lithophila* is a distinctive element of the flora of the southern Rocky Mountains. It has significant scientific, educational, and aesthetic values (Peterson et al. 1983). Of its five closest relatives in the genus *Aletes*, four are also narrow endemics (*A. anisatus*, *A. humilis*, *A. macdougalii* ssp. *breviradiatus*, and *A. sessiliflorus*), and the fifth is a regional endemic (*A. macdougalii* ssp. *macdougalii*) (Theobald et al. 1964). Thus, *N. lithophila* belongs to a complex of interesting species.

Neoparrya lithophila was a mystery for many years, and its rediscovery is a classic example of botanical detective work. It was first collected in 1867 by C.C. Parry, the botanist with the Pacific Railway Expedition. Parry collected it while the party was trying to find a potential route over the Sangre de Cristo Mountains, focusing on the area around La Veta Pass. It was not described until 1929 when Mildred Mathias, an expert on the Apiaceae, critically examined Parry's specimens. She decided the plant was so distinctive that it deserved generic recognition, and she named the new genus after Parry. However, it was many years before this species was collected again.

Colorado Native Plant Society (1997) summarized the story of the rediscovery of *Neoparrya lithophila* as follows:

"In her original description, Dr. Mathias stated that the Parry specimen had been found at Huerfano Peak in Taos County, New Mexico. By the mid-1950s, after repeated failures at finding the plant in northern New Mexico, she and other workers decided that Parry must have collected the plants elsewhere. William A. Weber of the University of Colorado tried to reconstruct Parry's route. Parry was a member of an expedition studying the feasibility of a railroad route, so documentation did exist as to the location of the party at specific times. But it was Parry's own personal notebooks, preserved at Iowa State University, that proved most helpful as to when and where plant collections were made. The one critical element lacking was the exact date of the collection. Parry's specimen label indicated September, but by early September the party was making its way quickly south to Santa Fe and not collecting plants. Dr. Weber concluded that the only logical place was in the valley below Sangre de Cristo Pass in today's Huerfano County, Colorado. He was right! After a brief search of the area he found rock-loving neoparrya [Neoparrya lithophila] growing in a crevice in a bare rock wall. The date of rediscovery was June 29, 1957- 90 years after the Parry collection. It was found later that specimens of rock-loving neoparrya had been collected in 1922 in Saguache County by C.E. Taylor. However, Taylor's plants were misidentified and filed away under a different name until the 1980's, when Ronald Hartman of the University of Wyoming recognized them."

Mathias (1929), Weber (1958), and Peterson et al. (1983) offer more complete documentation of the fascinating history of the knowledge of this species.

Although there is strong evidence (cited in Weber 1958) that Parry made his collections at the presumed type locality in Huerfano County, Colorado, Hartman's recent discovery of this species in New Mexico reopens the possibility that Parry was indeed in New Mexico when he collected this species in the "Huefano Mountains."

Members of both *Aletes* and *Neoparrya* are typically found in xeric sites that are mostly open, exposed, rocky or sandy (Theobald et al. 1964, Spackman et al. 1997). *Neoparrya lithophila* is acaulescent (nearly stemless) and herbaceous, and it produces new leaves and leafless inflorescences each year. The plants are caespitose, taprooted, and 8 to 29 cm high (**Figure 1**; Theobald et al. 1964). Large clumps of vegetation more than two feet in diameter can form, but it is sometimes unclear whether these clumps are a single individual or represent multiple individuals that have coalesced (Colorado Natural Heritage Program 2004). Members of *Aletes* and *Neoparrya* are xeromorphic (morphologically adapted to dry conditions) and have thick, glossy, leathery leaves (Weber 1958). The leaves are once pinnate, with linear, remote pinnae that are 5 to 32 millimeters long and 1.5 to 4 millimeters broad (**Figure 2**; Theobald et al. 1964).

The small, yellow flowers of *Neoparrya lithophila* are protogynous, meaning the styles are receptive before the stamens dehisce (**Figure 3**). Thus, the flowers are functionally unisexual. This is a major synapomorphy among western North American Apiaceae; most eastern genera are protandrous, in which the stamens dehisce first (Hartman personal communication 2002). A finite number of seeds are produced on each globose inflorescence. The fruit is a schizocarp, consisting of two one-seeded mericarps suspended by a carpophore (Heywood 1993, Hartman personal communication 2002). The carpophore is a dry, wiry remnant of vascular tissue. The fruits are oblong, 3.5 to 5 millimeters long, with deltoid ribs (Hartman personal communication 2002). The fruit has scent that cures to fresh peaches when crushed (Johnston personal communication 2002).

Several characters distinguish *Neoparrya lithophila* from members of the closely related genus *Aletes* and other genera in Apiaceae. Among these is the arrangement of oil tubes (vittae) in the wall of the fruit (pericarp), which has been considered taxonomically important for members of the Apiaceae. Most members of the genus *Aletes* (as circumscribed by Theobald et al. 1964) have one oil tube centered between each rib of the pericarp. *Neoparrya lithophila* has oil tubes scattered throughout the pericarp, suggesting that it deserves generic recognition (Mathias 1929, Theobald et al. 1964, Hartman 1984, Kartesz 1999). However, in his revision of the genus *Aletes*, Weber (1984) included *N. lithophila* as *A. lithophilus*. He believed that too much emphasis had been placed on too few characters in classifying many North American umbels, including *N. lithophila*. When all of the morphological characteristics, habitat, chemistry, phytogeography, and ecology were taken into account, the weight of evidence suggested to him that it was congeneric with other members of *Aletes*.

Downie et al. (2002) questioned the value of fruit characters (including those pertaining to oil tubes) for phylogenetic inference due to their variability within genera. Given the need for a major recircumscription of the Apioideae, there may be further nomenclatural changes for *N. lithophila* in the future. In this species assessment, this species is treated as *N. lithophila* to adhere to the nomenclature of Kartesz (1999).

Neoparrya lithophila is distinguished from *Aletes humilis* and *A. acaulis* in having linear lateral leaf lobes rather than broad and incised lobes with flaring tips. It also differs from these species, as well as *A. anisatus* and most other members of the Apiaceae, in having reflexed umbel rays, giving the inflorescence a ball-shaped appearance. Although it is quite aromatic, it lacks the strong anise odor of *A. anisatus*. Johnston (personal communication 2002) likens the aroma to pungent sweet turpentine. Its bright green color is distinctive, but it may be mistaken at a distance for *Gutierrezia sarothrae* or *Hymenoxys richardsonii*.

Neoparrya lithophila is diploid with a haploid chromosome number of n=11 (Crawford and Hartman 1972). In the subfamily Apioideae, 60 percent of the species thus far studied have a haploid chromosome number of n=11, although the haploid chromosome number ranges from 4 to 77 (Moore 1971).

Figure 1. *Neoparrya lithophila* in fruit on September 3, 2004. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

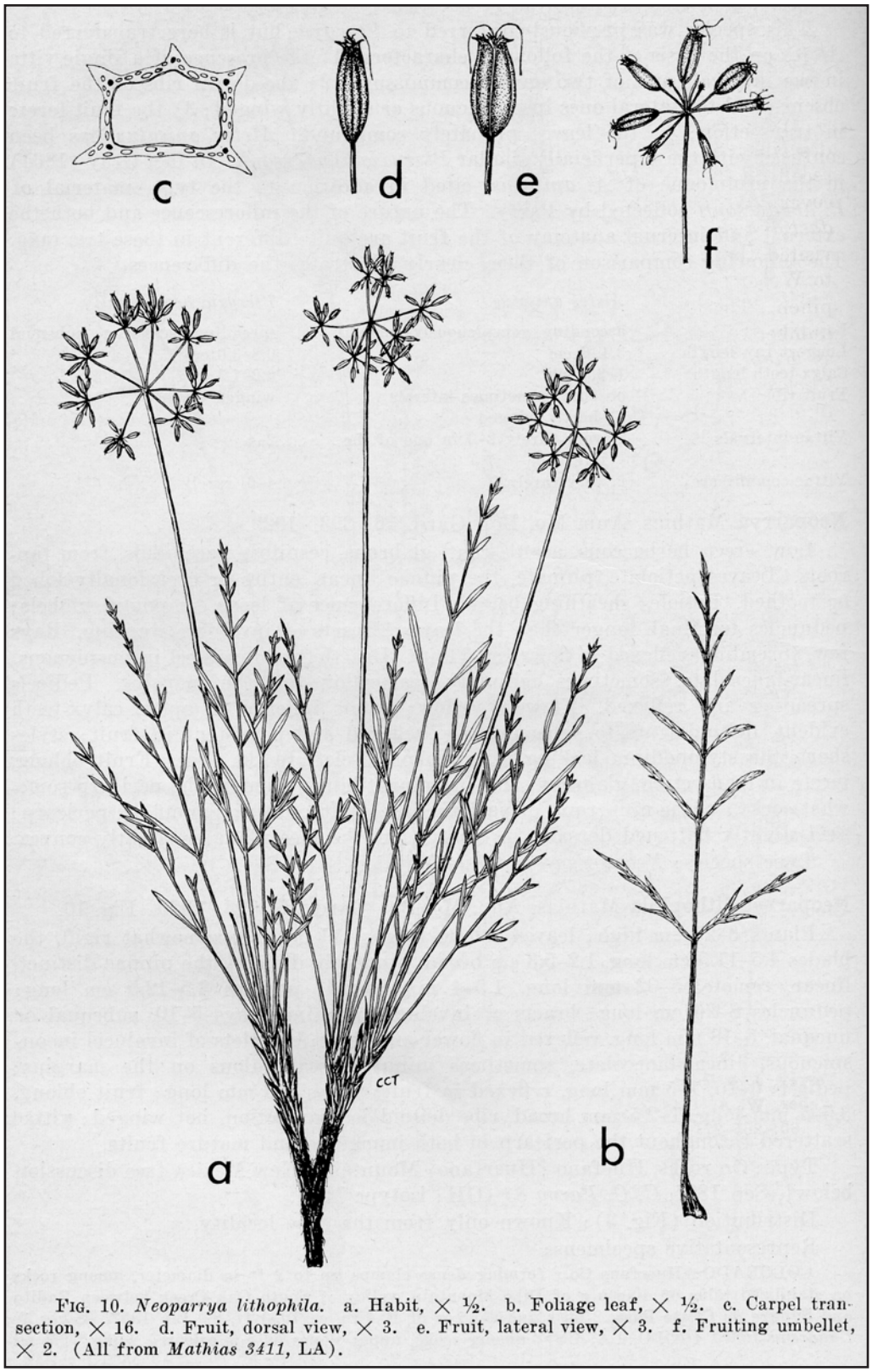

Figure 2. Illustration of *Neoparrya lithophila.* Public domain illustration from Theobald et al. (1964).

Figure 3. *Neoparrya lithophila* in flower. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

Several sources are available for further technical information on *Neoparrya lithophila*. The most useful of these is Theobald et al. (1964), which includes a full technical description and an excellent illustration (included as **Figure 2**). Spackman et al. (1997) include a description, illustration, photographs of the plant and its habitat, and a range map, as well as useful field identification characteristics. The Colorado Native Plant Society (1997) also includes a good photograph. Mathias (1929) includes a photograph of the type specimen. The type specimen of *N. lithophila* is housed at the Gray Herbarium of Harvard University, with isotypes housed in the Missouri Botanical Garden Herbarium.

Distribution and abundance

Neoparrya lithophila has a somewhat restricted range. It is endemic to the southern Rocky Mountains (**Figure 4**; Weber 1958, Neely et al. 2001). It is known from seven counties in south-central Colorado: Chaffee, Conejos, Fremont, Huerfano, Mineral, Rio Grande, and Saguache (Colorado Natural Heritage Program 2004). The known occurrences are found on lands managed by BLM, USFS, State of Colorado, and City of Del Norte lands, on a preserve owned by The Nature Conservancy, and on private lands (**Table 2**). Most occurrences are known from the western rim of the San Luis Valley, but important outlying occurrences are also found in the Arkansas Valley in the Salida area and at Farisita Dike in Huerfano County (**Figure 5**). Distribution data for the known occurrences in Region 2 are summarized in **Table 3**. *Neoparrya lithophila* is very likely to be found in the San Luis Hills of Costilla County as well. The flora of Costilla County has not been well documented, and thorough surveys are needed.

Neoparrya lithophila also has been found recently in north-central New Mexico by Ron Hartman. The location of this occurrence remains undisclosed pending publication of this research (Hartman personal communication 2002, 2004).

Thirty-eight occurrences are known and mapped by the Colorado Natural Heritage Program; some of these are composed of several discrete patches

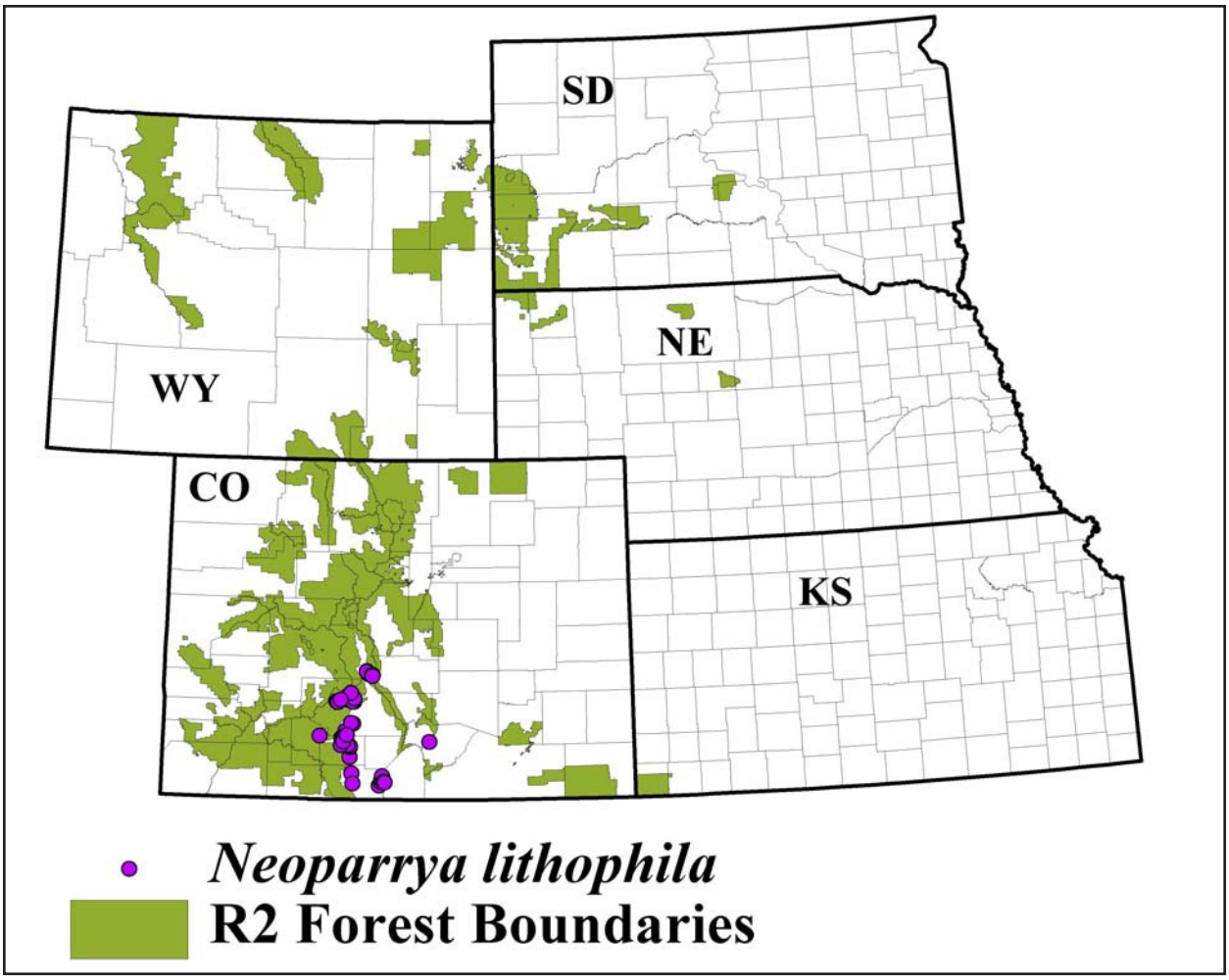

Figure 4. The distribution of *Neoparrya lithophila* in the states of USDA Forest Service Region 2 (Colorado Natural Heritage Program 2004).

Table 2. Land ownership status of the 38 known occurrences of *Neoparrya lithophila* in Region 2. Because some occurrences are found on two properties, the total is less than the sum of the rows in the table. **See Table 3** for management of specific occurrences.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service	10	
Rio Grande National Forest		6
San Isabel National Forest		4
Bureau of Land Management	26	
San Luis Field Office		23
Royal Gorge Field Office		3
Colorado Division of Wildlife	1	
State of Colorado Land Board	2	
City of Del Norte	1	
The Nature Conservancy	1	
Other Private	4	
State Natural Area	1	
TOTAL	**38**	

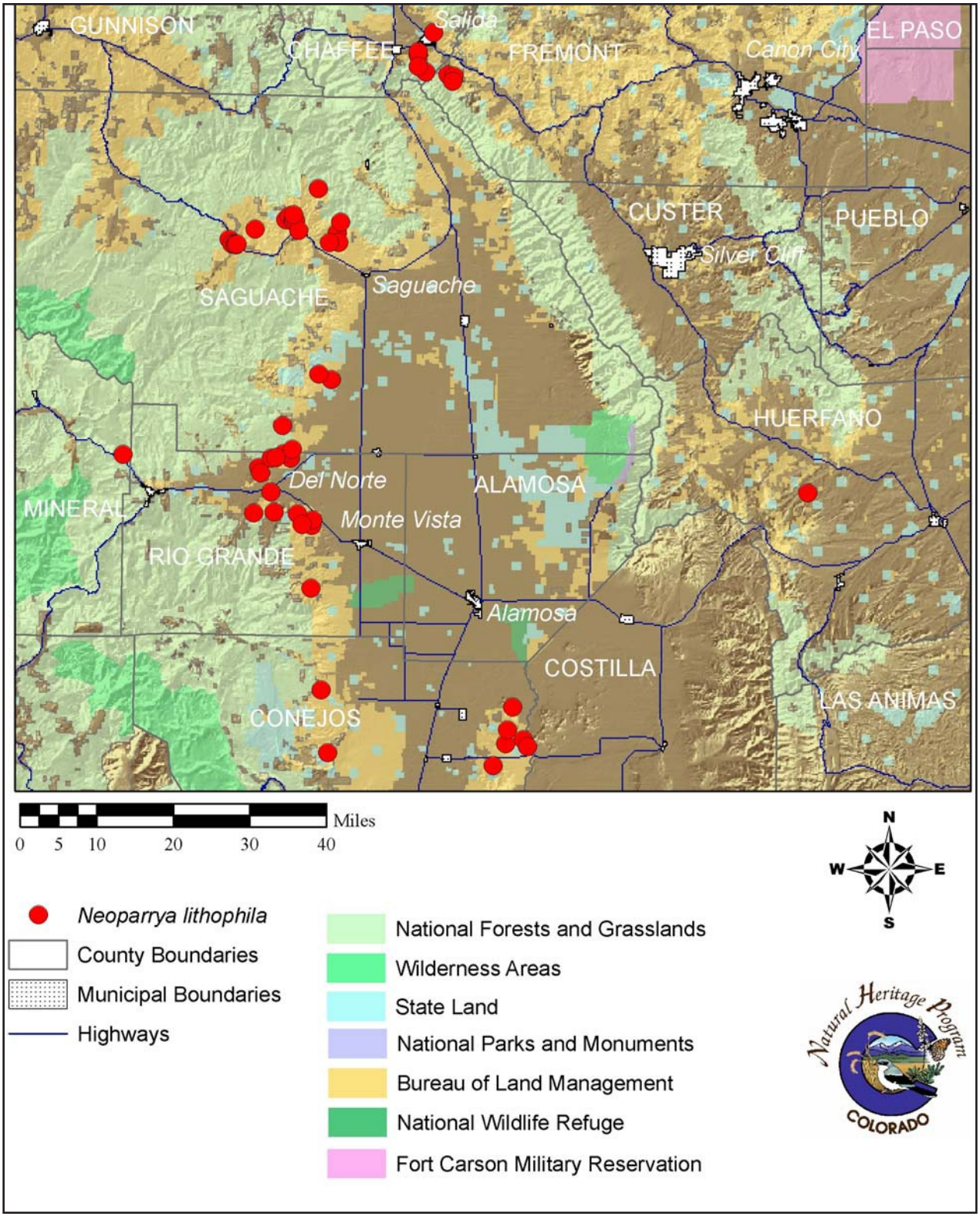

Figure 5. Known distribution of *Neoparrya lithophila* in Colorado, showing relationship to counties, physiographic features, municipalities, roads, and land management.

Table 3. Summary information for the 38 known occurrences of *Neoparrya lithophila*. Source I.D. is Colorado Natural Heritage Program element occurrence number unless otherwise noted. Management is bold for occurrences on USDA Forest Service land.

Source I.D.	County	Management	Last Observed	Location	Elevation (ft)	Population Size (no. of plants)
1	Huerfano	Private: The Nature Conservancy	1993	Farisita Dike	7,390	1,000 to 2,000
2	Saguache	Bureau of Land Management: San Luis Field Office	8/22/1997	Upper Saguache Guard Station/ Taylor Canyon	8,440 to 8,685	3,250 to 3,450
3	Saguache	Bureau of Land Management: San Luis Field Office	7/11/1999	Middle Creek	8,200 to 8,700	~3,000
6	Saguache	**USDA Forest Service: Rio Grande National Forest**/Private	6/30/1997	660 Road	8,200 to 8,648	~5,400
7	Saguache	State of Colorado Land Board	10/21/1997	Cottonwood Creek	7,900	less than 1,000
8	Rio Grande	**USDA Forest Service: Rio Grande National Forest**/Elephant Rocks State Natural Area/BLM: San Luis Field Office (Elephant Rocks Area of Critical Environmental Concern)	8/18/2003	Elephant Rocks	7,950	~2,320
9	Chaffee	Private/Bureau of Land Management: Royal Gorge Field Office	5/21/2001	Salida	7,280 to 7,600	500 to 1,000
10	Conejos	Bureau of Land Management: San Luis Field Office (San Luis Hills Area of Critical Environmental Concern)	9/11/1999	Flat Top	8,300 to 9,100	1,500 to 2,000 (6,000)
12	Rio Grande	State of Colorado	11/1/1999	Rock Creek Gaging Station	8,320 to 8,460	more than 2,000
13	Rio Grande	Bureau of Land Management: San Luis Field Office	7/18/1999	Dry Pole Creek	8,300	60 to 70
14	Conejos	Bureau of Land Management: San Luis Field Office	7/10/1999	Canyon Del Rancho	8,280 to 8,780	more than 3,000
15	Rio Grande	**USDA Forest Service: Rio Grande National Forest (Spring Branch Research Natural Area)**	8/25/1999	Spring Branch RNA	8,700 to 9,060	3,000 to 3,500
16	Rio Grande	Bureau of Land Management: San Luis Field Office	8/27/1999	Limekiln Creek Uplands	8,120 to 8,200	more than 5,000
17	Rio Grande	Private	8/26/1999	Dry Pole Creek Uplands	8,400 to 8,600	more than 2,000
18	Rio Grande	Bureau of Land Management: San Luis Field Office	8/23/1999	Limekiln Creek Uplands	7,960 to 8,040	more than 1,500
19	Conejos	Bureau of Land Management: San Luis Field Office (San Luis Hills Area of Critical Environmental Concern)	9/10/1999	Pinyon Hill	8,240 to 8,400	250
20	Conejos	Bureau of Land Management: San Luis Field Office (San Luis Hills Area of Critical Environmental Concern)	9/14/1999	North San Luis Hills	7,580 to 7,740	at least 300
21	Conejos	Bureau of Land Management: San Luis Field Office (San Luis Hills Area of Critical Environmental Concern)	9/11/1999	North Pinyon Hills	7,880	90
22	Conejos	Bureau of Land Management: San Luis Field Office	9/14/1999	North San Luis -Fairy Hills	7,740 to 7,760	~150

Source I.D.	County	Management	Last Observed	Location	Elevation (ft)	Population Size (no. of plants)
23	Rio Grande	Private	6/29/1999	Indian Head	8,050 to 8,500	at least 1,000
24	Conejos	Bureau of Land Management: San Luis Field Office (Rio Grande River Corridor Area of Critical Environmental Concern in part)	9/14/1999	North San Luis-Fairy Hills	7,550 to 7,882	300 to 400
25	Rio Grande	**USDA Forest Service: Rio Grande National Forest**/Bureau of Land Management: San Luis Field Office/Private	6/21/1999	East Butte	8,090 to 8,860	7,000 to 8,000
26	Rio Grande	Bureau of Land Management: San Luis Field Office	9/12/1999	Limekiln Creek Uplands	7,880	700
27	Conejos	Colorado Division of Wildlife	6/28/1999	Hot Creek State Wildlife Area	8,160 to 8,400	3,000 to 4,000
Elliott 9066; pers. comm. Elliott 2004	Chaffee	**USDA Forest Service: San Isabel National Forest**	2004	Methodist Mountain	8,700 to 9,300	not reported
Elliott 6728	Saguache	Bureau of Land Management: San Luis Field Office	6/8/1999	Dry Gulch	9,200	not reported
Hartman 66135	Saguache	Bureau of Land Management: San Luis Field Office	8/17/1999	Bachiche Spring/ Garcia Spring	8,600 to 9,300	not reported
Hartman 66418	Saguache	Bureau of Land Management: San Luis Field Office	8/22/1999	Dry Creek Road	8,200 to 9,300	not reported
Hartman 66488	Saguache	Bureau of Land Management: San Luis Field Office	8/22/1999	Dry Creek Road	9,400 to 9,800	not reported
Hartman 66532	Saguache	**USDA Forest Service: Rio Grande National Forest**/Bureau of Land Management: San Luis Field Office	8/22/1999	Poison Gulch Road	8,400 to 9,000	not reported
Hartman 66533, 66629, 66630	Fremont	**USDA Forest Service: San Isabel National Forest**/Bureau of Land Management: San Luis Field Office/State of Colorado Land Board	8/23/1999	Spring Gulch Rimrock	7,800 to 9,000	not reported
Elliott 11675; pers. comm. Elliott 2004	Fremont	**USDA Forest Service: San Isabel National Forest**/Bureau of Land Management: Royal Gorge Field Office	9/13/2004	Bear Creek	9,400 to 9,683	thousands
Holt 648	Chaffee	Bureau of Land Management: Royal Gorge Field Office	6/12/2000	Spiral Drive	7,400 to 7,987	not reported
Holt 1145	Chaffee	**USDA Forest Service: San Isabel National Forest**	6/24/2000	Rainbow Trail	~8,800	not reported
Flaig 3403	Saguache	Bureau of Land Management: San Luis Field Office	5/27/2004	Cottonwood Creek	8,050	~300
Flaig 3628	Saguache	Bureau of Land Management: San Luis Field Office	5/30/2004	Trickle Mountain	9,240	~50
Flaig 5518	Mineral	**USDA Forest Service: Rio Grande National Forest**	7/8/2004	Rio Grande Palisades	9,170	~10
Flaig 6238	Rio Grande	City of Del Norte	7/21/2004	Del Norte	8,200	not reported

(suboccurrences) (**Table 3**; Colorado Natural Heritage Program 2004). Ten occurrences are located on USFS lands: six on the Rio Grande National Forest and four on the San Isabel National Forest. The Colorado Natural Heritage Program estimates that 10 to 20 occurrences remain to be documented: five to 10 more in the San Luis Hills of Conejos and Costilla counties, and five to 10 more in the foothills of Rio Grande County. More are also possible in Mineral County (Flaig personal communication 2004) and in other areas as well.

Based on available element occurrence data, the estimated total number of individuals for *Neoparrya lithophila* falls between 48,680 and 58,490 individuals, with additional individuals unaccounted for in occurrences where population size was not estimated (Colorado Natural Heritage Program 2004). Of these, approximately 9,500 individuals have been estimated within occurrences on USFS land, although population size was not estimated at four occurrences on USFS land (**Table 3**). Known occurrences of *N. lithophila* range in size from approximately 10 individuals to approximately 8,000 at East Butte in Rio Grande County. Population size estimates for all known occurrences are included in **Table 3**. Nine of the known occurrences are considered excellent (thus receiving an element occurrence rank of "A") by the Colorado Natural Heritage Program (2004). Of these, four (EO 6, 8, 15, and 25) are on the Rio Grande National Forest. The criteria for determining this quality rank are population size, size of occupied area, condition of the habitat, and landscape context of the surrounding area. Excellent occurrences represent the highest priority conservation areas. For *N. lithophila*, an excellent occurrence typically consists of more than 3,000 individuals. However, smaller populations of this species appear to be viable and have shown no signs of decline due to inbreeding depression. Thus, most known occurrences of this species are worthy of conservation efforts if the opportunity arises. Element occurrence ranks for the known occurrences in Region 2 are summarized in **Table 4**.

Occurrences of *Neoparrya lithophila* are naturally isolated by the discontinuity of suitable habitat (Peterson et al. 1983, Carron 1990). The dikes and cliffs on which most occurrences reside project many hundreds of feet above their surroundings. The interstitial landscape is underlain primarily by Eocene sedimentary rocks such as the Cuchara formation, on which *N. lithophila* apparently does not grow (Tweto 1979, Colorado Natural Heritage Program 2004).

Recent survey work in Saguache, Rio Grande, and Conejos counties by the Colorado Natural Heritage Program (Rondeau et al. 1998, Kettler et al. 2000) has greatly improved our understanding of the distribution of this species. It was also collected 13 times by Brian Elliott and Ron Hartman (Elliott 2000), seven of which represent previously undocumented element occurrences; they were also the first to document this species in Fremont County. Emily Holt (Holt 2002) collected it three times, two of which represent previously undocumented occurrences. Ongoing work by Jeanette Flaig in the eastern San Juan Mountains resulted in five more collections in 2003 and 2004, four of which represent new occurrences and one of which is a county record for Mineral County. If other occurrences are found, some occurrences will be found to be less isolated than currently believed.

Population trend

There is no evidence of either population decline or increase in *Neoparrya lithophila* (Peterson et al. 1983, Carron, 1990, Hartman personal communication 2002), but there has been only one study from which insight into population trend can be gleaned. Four years of monitoring data (1990, 1991, 1992, and 1994) were gathered by The Nature Conservancy at Farisita Dike for *N. lithophila* (Schulz personal communication 2002). The first three years were available for analysis and inclusion in this assessment. These data track 298 individuals and include data on size and number of flowering stalks. Although these data were not originally gathered to obtain demographic information on the species, they can be used to make some inferences. In September of 1992, 14 plants that had been initially tagged in 1990 were missing from monitoring plots (presumed dead) or confirmed dead. However, 30 seedlings were observed within 50 centimeters of the marked plants in 1992. Most plants live considerably longer than three years, and the population size does not fluctuate greatly from year to year. That all plants were seen repeatedly until death suggests that *N. lithophila* does not exhibit prolonged dormancy.

While there are no data from which population trend can be quantified for all other known occurrences, observations of impacts from recreation and grazing suggest that there have been some downward trends locally. The magnitude of these impacts to the viability of the occurrences has not been rigorously assessed.

Habitat

Neoparrya lithophila occurs in the Temperate Steppe Division of the Dry Domain in the Ecoregion classification of Bailey (1995). Within the Temperate

Table 4. Summary of habitat and element occurrence data with management comments noted for the 38 known occurrences of *Neoparrya lithophila*. Source I.D. is bold for occurrences on USDA Forest Service land. Key to element occurrence ranks: A – excellent estimated viability; B – good estimated viability; C – fair estimated viability; E – not evaluated. See **Table 3** for details on county, land management, last observation, location, elevation, and population size. Source I.D. is Colorado Natural Heritage Program element occurrence number unless otherwise noted.

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
1	The site consists of a tertiary volcanic dike rising approximately 300 feet above the surrounding gently rolling valley of Yellowstone Creek. This more erosion-resistant igneous dike protrudes out of the Eocene sandstones of the Cuchara formation. The dike is longitudinally oriented east-west and is approximately .5 miles long and .1 mile wide. *Neoparrya lithophila* occurs along the ridgetop and north slopes of the dike in cracks and among stabilized talus, and on shelves along small cliffs. The site contains a high-quality example of the *Pinus edulis/Elymus ambiguus* community.	Forming large clumps up to two feet in diameter. Flowers yellow.	The population can be protected by fencing the dike area to exclude grazing and people. The majority of plants occur in rocky areas that cattle could not reach, but 10 to 20 percent of the population is more accessible. Usage should be restricted to scientific research and management.	B
2	On volcanic rimrock and on rock mound. Associated taxa: *Rhus* spp., *Ribes* spp., *Artemisia frigida*, *Festuca* spp., *Hymenoxys richardsonii*, and *Muhlenbergia filiculmis*. Geology: Carpenter Ridge volcanic rimrock. Aspect: All (N+). Soil: coarse, sandy loam, gravelly. Slope: 5 to 60 percent.	This element occurrence has a total of five suboccurrences. Volcanic outcrop, coarse volcanic soil at base of knoll and in cracks in smooth rock surface. Most of the mid-slope plants had their fruit grazed. Deer and elk droppings were present. Fruits at lower elevation (at base of rocks) were fresher than those at the top of rock. Most plants on south to southwest facing slopes.	At one site, current management was adequate. No off-road vehicle use present in 1997. Exclusion of off-road vehicle use would benefit this occurrence. If highway was ever widened, this occurrence may be severely affected. At another site, the area was fenced off. Did not notice any signs of horses or other domestic livestock. One portion of the occurrence is fenced off, with no signs of horses or other domestic livestock. Another portion is currently used as horse pasture, but this does not appear to be a problem for the plant. Grazing was noted as heavy at one suboccurrence.	B
3	Volcanic (basaltic, rhyolitic, or tuff ridges). Primarily running north-south and drainage below. Shortgrass dominates, even on the steep rocky slopes. Many of the slopes are steep (approximately 50 percent grade) with cliffs on the top. Lichens dominate the rocky outcrops. Geology: Carpenters Ridge. Soils: coarse. Associated taxa: *Ribes* spp., *Pinus* spp., *Festuca* spp., *Artemisia frigida*, *Chrysothamnus* spp., and *Bouteloua* spp.	Densest part of occurrence is located on or near the ridge tops and the north-facing slopes. It is also found below the ridges of the west-facing slopes, but the numbers are lower. Grassland with *Festuca arizona*, *Muhlenbergia montana*, and *M. filiculmus* the dominant grasses. 75 percent fruit. Few non-natives, habitat is largely unfragmented.	Current management is adequate. Maintain as is.	B
6	Area is comprised of rolling, more or less east-west ridges of black volcanic rock (basalt?). Ridge hill tops scattered with *Pinus edulis*, occasional *Juniperus monosperma*, with occasional shrubs of *Rhus trilobata* and *Cercocarpus montanus*. Understory grasses on hill tops are *Bouteloua gracilis*, *Stipa comata*, *Oryzopsis hymenoides*, *Muhlenbergia* spp., *Koeleria macrantha*, and *Aristida purpurea*. Forbs include *Artemisia frigida*, *Eriogonum jamesii*, *Chenopodium* spp., *Mirabilis* spp., *Hymenoxys richardsonii*, *Chrysothamnus* spp., *Ribes* spp., *Bouteloua* spp., *Muhlenbergia* spp., and *Poa* spp. The overall vegetation is open and sparse with *Neoparrya lithophila* often the dominant forb on the ridge tops. Aspect: northwest. Soil: gravelly sandy loam dark. Slope: 10 to 70 percent.	The bulk of the occurrence is found on the ridge top and tapering off as one walks down the north-facing slope. Very few individuals on the south-facing slope. Approximately 80 percent of individuals in fruit. Plants occur on flat "benchlets" or in cracks among volcanic rocks. Plants very robust. No evidence of grazing. Too rocky and steep for off-road vehicle use. Favors undisturbed areas. No non-native species observed.	Current management adequate. Current threats low. Low recreation use on National Forest System land, mostly limited to valley bottom with little effects on occurrence. At least half of this entire occurrence is located on private land. A conservation easement would be desirable. Avoid overgrazing.	A

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
7	Geology: precipitous volcanic outcrop. Aspect: west and southwest. Soil: gravelly sandy loam. Slope: 5 to 150 percent. Associated taxa: *Ribes* spp. *Stipa* spp. *Bouteloua* spp., *Koeleria* spp., and *Eriogonum* spp.	Plants growing in soil pockets and in cracks among rocks, from cliff base to cliff face; favors stable areas; does not occur on moving scree. Very steep and rocky: no disturbance.	Not available.	C
8	Geology: volcanic overflow. Aspect: various. Slope: 0 to 60 percent. Open pinyon-juniper community. In soil pockets, outwash, and protected spots, needs stable soil. Shade form protected by overhanging boulders. Scattered on flat soil pockets and in crevices on boulders. Growing in cracks, soil pockets and sometimes between rounded, room-sized boulders of Fish Canyon volcanic formation. Associated taxa: *Ribes cereum*, *Eriogonum jamesii*, *Opuntia polycantha*, *Yucca* spp., *Artemisia dracunculoides*, *Echinocerus triglochidatus*, *Cercocarpus* spp., *Muhlenbergia* spp., *Bouteloua* spp., *Oryzopsis* spp., and *Symphoricarpos* spp.	Mid to late fruit, no flowers seen. Shade-form. Scent sweet-pungent turpentine, curing to scent of strong peaches.	Rocks with little human use. Open grasslands between outcrops overgrazed.	A
9	Tan or white foothills formed of erosive badlands of Dry Union Formation (Pliocene lacustrine). Barren, steep, eroded silt loam hills and slopes below cliffs in Dry Union Formation. Plants growing on fine-textured soils with approximately 80 percent bare ground. Nearly barren alluvium. Growing in small "cove" in hills. Aspect: northwest. Soil: alluvium, sandy silt. Slope: 5 to 50 percent. Associated taxa: *Juniperus* spp., *Chrysothamnus* spp., *Artemisia frigida*, *Eriogonum jamesii*, *Cercocarpus montanus*, *Thermopsis divaricarpa*, *Astragalus* spp., *Oryzopsis hymenoides*, and an unknown shrub (possibly an Eleagnaceae). Bordering a *Pinus edulis* and *Cercocarpus montanus* community. Pinyon/juniper slopes and sandy clay badlands.	Plants fairly evenly distributed with plants within 3 to 10 feet of each other. Plants appear healthy and robust in 100 percent fruit. Plants of many sizes observed with some forming large rounded clumps 2 feet in diameter. One of most abundant species in habitat. High reproductive output and occurrence is apparently healthy.	No management problems observed. Threats: none apparent. Recommend special designation. Site not likely to be developed. Site not grazed. Terrain precludes development. Access limited. No evidence of current use observed.	A
10	The plants occur on the north side of a series of steep cliffs at the base, on rock outcrops and small cliffs, and on a relatively flat saddle near the mesa top. Plants occur either in cracks in the rocks or on very gravelly flats (on the saddle). Steep hillsides of dark volcanics; growing along cracks. From 3/4 up to top on cliffs. Most plants are on a west slope. Aspect: west and southwest. Light exposure: full sun, part shade. Moisture: xeric. Geology: Servilleta basalt and red scoreaceous material in places. Soil: weathered lava. Slope: 40 to 60 percent. Associated species: *Bouteloua gracilis*, *Heterotheca villosa*, *Eriogonum jamesii*, *Stipa scribneri*, *Artemisia frigida*, *Opuntia polyacantha*, *Fallugia paradoxa*, *Pinus edulis*, *Elymus elymoides*, *Oryzopsis hymenoides*, and *Artemisia* spp.	Flower color: yellow. 1 percent in flower. 99 percent in fruit. No evidence of disease, predation, or injury. The habitat for the plant is relatively pristine, but the lower slopes and bottom have a lot of *Salsola* spp. Very steep and therefore undisturbed, plants abundant.	No management needed. Exotic species: *Salsola* spp.is common below the occurrence on the valley floor. Area reported to have been grazed by wild horses in past, but not likely where plant occurs. Inaccessible to domestic stock other than goats.	A

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
12	Plants growing in rock cracks below cliffs and along cliff edge. Few other species grow directly adjacent to occurrence. Species commonly growing nearby include: *Bouteloua gracilis*, *Sporobolus* spp., *Holodiscus* spp., *Yucca* spp., *Echinocerus triglochidatus*, *Opuntia* spp, *Eriogonum jamesii*, *Heterotheca villosa*, *Atriplex* spp., *Chrysothamnus nauseousus*, and *C. greenei*. Aspect: south to southwest. Percent slope: 30 to 60 percent. Moisture: xeric. Parent material: volcanic. Soil: very little. Landform: cliff and rocky slope.	Flower color: yellow. Vegetative: 100 percent. Reproductive success: plants have old flowering stems.	Area is heavily used for recreation. Private land adjacent is not protected. Trash pick-up badly needed; garbage and broken glass everywhere. Lots of graffiti on the cliffs. Area along creek below cliffs very heavily impacted by recreational users. Plants growing below cliffs have obviously been trampled in a few cases. Area above cliffs much less impacted. Some plants threatened by recreational use below cliffs. Above cliffs, naturally protected by difficult access. Exotic species: *Poa pratensis* in creek bottom.	A
13	On south facing cliffs in the cracks of rocks and in the gravel over rock. Occurrence is only about 50 feet in extent even though very similar habitat exists on either side. Most plants are on flat rock on the cliff face in protected areas (small cave). Aspect: south. Light exposure: full sun. Moisture: xeric. Associated taxa: sparsely vegetated.	Fruit: 100 percent. Reproductive success: small and large plants present. Evidence of disease, predation, or injury: none. Size: less than 1 acre. Relatively unfragmented but numerous two tracks in the area.	No exotic species observed. Cliffs are not easily accessible, but mesa top is in only moderate condition.	C
14	Canyon consists of 30 to 40 foot vertical cliffs facing south for about 3/4 of a mile. Plants growing along top edge of cliffs and down vertical face in cracks, becoming dominant in some places. Aspect: south. Slope: 8 to 45 percent. Light exposure: full sun. Moisture: xeric. Parent material: volcanic. Soil: very little. Landform: cliff. Dominant plant community: cliff community. *Neoparrya lithophila* dominant in many places. Associated taxa: *Artemisia frigida*, *Bouteloua gracilis*, *Eriogonum jamesii*. Other species nearby include: *Heterotheca villosa*, *E. jamesii*, *Yucca glauca*, *B. gracilis*, *Rhus trilobata*, *Chrysothamnus nauseosus*, *Ipomopsis aggregata*, *Tetradymia* spp., and *Pinus edulis*.	Flower color: yellow. Vegetative: 15 percent. Flower: 1 percent. Fruit: 84 percent. Reproductive success: many fruits observed. Evidence of disease, predation or injury: none. Plants are dominant vegetation along top edge of cliff. Size of occurrence: 75 acres. Occurrence naturally protected by cliffs. Very little evidence of human disturbance. Cliffs in excellent condition.	Predominant land uses: recreation below cliffs. No evidence of grazing by sheep or cattle. Exotic species: none noted.	A
15	The plants occur on slightly sloping rocky areas and in the cracks on small cliffs on aspects ranging from west to northwest. A few plants occur on east facing parts of the cliffs but only a small proportion (10 percent). The cliffs and boulders are rounded to angular. Ridges and outcrops to the north and south are formed in platey rocks which do not appear to support the plant. Light exposure: full sun. Parent material: volcanic. Landform: mesa top. Associated taxa: *Muhlenbergia montana*, *Heterothera villosa*, *Erigeron* spp., and *Artemisia frigida*.	Flower color: yellow. Vegetative: 10 percent. Flower: 1 percent. Fruit: 90 percent. Reproductive success: many small plants observed, not sure of age. Evidence of predation, disease or injury: none. The Pinos Creek floodplain about one mile to the west is used for irrigated hay fields. Areas along San Francisco Creek about 2 miles east are being subdivided into 35 to 40 acre parcels. Natural communities dominate north and south.	Within the Spring Branch Research Natural Area. Little recent disturbance; some past wood cutting (minor) and two-track roads run near the occurrence; no non-natives were observed.	A

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
16	Plants occur on cliff edges and gently sloping rocky lobes on the north and west facing parts of the mesa. Similar geology on the south side was searched but did not support the species. In some places *Neoparrya lithophila* is the only species growing in the rocks. Several hundred *Cryptantha weberi* plants were also observed in the area. Aspect: west-north. Light exposure: full sun. Moisture: xeric. Parent material: volcanic. Associated taxa: *Bouteloua gracilis*, *Oryzopsis hymenoides*, *Elymus elymoides*, *Eriogonum jamesii*, *Phlox* spp., and *Koeleria macrantha*.	Vegetative: 10 percent. Fruit: 90 percent. Evidence of disease, predation or injury: none. Mostly surrounded by native plant communities for miles.	No exotic species noted. Many two tracks in the area and other signs of recreational use but not impacting the occurrence.	A
17	On the south slope of the mesa on flat rock "pavement" and in the cracks of steep cliffs. Scattered pinyon trees occur around the occurrence, other associated species include *Heterothera villosa*, *Bouteloua gracilis*, *Artemisia frigida*, and *Muhlenbergia montana*. Plants occur on the middle ridges or cliffs, not on the highest (except at the west end) or the lowest cliffs. Aspect: south. Light exposure: full sun, part shade. Moisture: xeric. Parent material: volcanic.	Vegetative: 10 percent. Fruit: 90 percent. Evidence of disease, predation or injury: none. Potential habitat to the east was surveyed but no plants were located. Large occurrence in very rough terrain. Subdivision to the south, irrigated meadows to the north.	Exotic species: none noted. No sign of disturbance near the plants, some grazing impact in valley below (south).	B
18	The plants occur on slightly sloping or flat rock "pavement" at the west end of the mesa. The plants generally grow in cracks in the rock with few other species. Associated species include *Phlox* spp., *Hymenoxys acaulis* (?), and *Bouteloua gracilis*. The plants are most common on aspects from northwest to southwest but also occur on the southerly aspects. Slope: 1 to 10 percent. Light exposure: full sun. Moisture: xeric. Parent material: volcanic.	Vegetative: 10 percent. Fruit: 90 percent. Reproductive success: many small plants. Evidence of disease, predation or injury: none. Size of occurrence: 5 to 10 acres. Large occurrence with healthy and robust individuals. Irrigated and developed land occurs about 1 mile to the northwest and a landfill about 1 mile to the south. Bureau of Land Management land to the west contains similar natural habitat for the species.	Significant increases in recreational use of the area (foot traffic and two tracks) could impact the plants. Some recreational impact from foot traffic but very minor. No non-natives observed. Part of the mesa has been quarried.	B
19	Plants occur mainly on the north side of a saddle between higher ridges in rocky "pavement", and or some large rock outcrops. Associated species include *Artemisia* spp. (possibly *A. bigelovii*), *Erigonum jamesii*, *Bouteloua gracilis*, *Koeleria macrantha*, and *Heterotheca villosa*. Aspect: north. Light exposure: full sun. Moisture: xeric. Parent material: red basalt like conglomerate.	Flower: 100 percent. Evidence of disease, predation, or injury: none. May be more plants east and west but not many would be expected considering density of plants at the site and limited habitat. Fairly small occurrence, small amount of suitable habitat. Highway 142 to the north but otherwise only a few two-tracks in the area.	*Salsola* spp. occurs lower on the slopes but not in the occurrence. Habitat is pristine but slopes below and stock ponds have patches of *Salsola* spp.	C

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
20	Rocky slopes are dominated by *Artemisia tridentata* ssp. *vaseyana*, *Bouetloua* spp., and lower flats are dominated by *Saracobatus vermiculatus* and *Chrysothamnus greenei*. Associated species include *B. gracilis*, *Eriogonum jamesii*, and *Arenaria fendleri*.	At least 300 plants, but much more similar habitat was not searched. The plants occurred on the north face of a mesa but mostly on the west side of ridges and small cliffs in cracks in the rocks. Suspect that there are at least several hundred more plants to the west. The area is dominated by native communities.	Near a county road but on steep slopes unaffected by it. Some irrigated fields occur to the east about ½ to 1 mile away.	C
21	On a small isolated rock outcrop. Most of the plants occur on the east face of the outcrop in cracks in the rock. A few occur at the base of the outcrop. The plants often occur in protected small coves or other protected microsites. Surrounding slopes and flats are dominated by sagebrush on rocky sites and green rabbitbrush on valley flats. Aspect: west. Light exposure: full sun/part shade. Associated taxa: *Stipa scribneri*, and *Bouteloua gracilis*.	Fruit: 100 percent. Evidence of disease, predation, or injury: none. Size of occurrence: less than 1 acre. Natural landscape for at least several miles in all directions.	Direct habitat is pristine but *Salsola* spp. is common along the nearby county road. Heavily used county road only 100 m from occurrence.	C
22	On the west slope of a narrow ridge in cracks in the rocks or very rocky soils. Associated species include *Stipa comata*, *S. scribneri*, and *Bouteloua gracilis*. The rocky slopes are dominated by *Artemisia tridentata* ssp. *vaseyana*, *B. gracilis*, and the lower valley floor is dominated by *Chrysothamnus greenei*, and *B. gracilis*.	Plants only at the southern end of a long narrow ridge with more suitable habitat. Condition and landscape context: two-tracks and a well-used county road occur in the area but otherwise the landscape is dominated by native communities for miles.	Some two-tracks in the area and signs of recreational use but no direct impact to the plants.	C
23	The occurrence is found from the bottom to the top of the volcanic cliffs. More concentrated on the shelves on the north side. Associated with *Ribes* spp., *Opuntia* spp., *Bouteloua gracilis*, *Artemisia frigida*, *Eriogonum* spp., *Echinocerus* spp., and *Phlox hoodii*. Plants occur in cracks and crevices with little competing vegetation although a few grow at the base of the cliffs where the grass is denser. The species also occurs in lesser quantities on a cliff to the north.	Plants occur scattered throughout the area toward the tops of cliffs and just below the rim and are most common on north facing cliffs. About 90 percent are fruiting, 5 percent flowering, and 5 percent are vegetative. Some small individuals occur, possibly indicating recruitment. Landscape is dominated by native vegetation.	No non-native species observed. The species is naturally protected by steep, inaccessible terrain and the occurrence is essentially undisturbed. The area about 2 miles to the west is being subdivided and developed.	B
24	The plants were most common on north aspects but also occurred on west facing and south facing slopes (only a few on south slopes). Most occurred in cracks of rocky cliffs or very rocky places below the cliffs. Associated species include *Koeleria macrantha* and *Arenaria fendleri*. Rocky cliffs and outcrops dominated by *Artemisia tridentata* ssp. *vaseyana* and *Bouteloua gracilis* above the valley floor which was dominated by *Chrysothamnus greenei* with *B. gracilis*. Slope: 0 to 100 percent. Aspect: south, west, north. Soils: rocky or cliffs. Geologic substrate: volcanic.	Additional suitable habitat was searched in the area, but this may be at the lower elevational limit for the species, possibly explaining why more plants were not located. Condition is pristine where the plants are located; the riparian area along the Rio Grande is degraded from summer cattle grazing. Native communities dominate for miles in all directions.	No management actions needed. On very, very steep areas. Several two tracks occur near the occurrence. A well-used county road occurs nearby to the west. None appear to impact the plants.	C

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
25	Occurs in cracks in boulders and other somewhat protected microsites on all aspects of dry volcanic cliffs. Associated species are sparse but include *Oryzopsis micrantha*, *Ribes* spp., *Poa* c.f. *secunda*, *Echinocerus triglochidatus*, *Heterotheca villosa*, *Bouteloua gracilis*, *Artemisia frigida*, and *Eriogonum* spp.	About 90 percent of the plants were in fruit, 5 percent in flower, and 5 percent vegetative only. Numerous sizes were present possibly indicating recruitment. Plant are scattered to dense along the cliffs but most concentrated near the top of cliffs and in small, protected draws on all aspects. The surrounding landscape is dominated by natural vegetation for several miles.	There is little disturbance to the occurrence because of the inaccessible area in which the plants grow. No non-native species were observed.	A
26	The rock outcrops occur in rolling shrublands dominated by *Chrysothamnus greenei* and *Bouteloua gracilis*. Large mesas occur throughout the area. Associated species include *C. greenei*, *B. gracilis*, *Artemisia purpurea*, *Eriogonum jamesii*, *Heterotheca villosa*, *Penstemon linarioides* ssp. *coloradoensis*, *Potentilla* spp., and *Oreocarya weberi*.	Plants occur on relatively flat rock "pavement" or very slightly north sloping rock. 1 to 2 acres of habitat.	If recreational use increases significantly, it could impact the occurrence. The occurrence may have been impacted by past rock mining. Currently there is a lot of recreational use near the occurrence: target practice, numerous two-tracks in the area. *Kochia* spp. and *Salsola* spp. are common where there is disturbance (below the occurrence). A powerline crosses the occurrence. Highway 160 is nearby and the county landfill is 1 to 2 miles to the south. Numerous well-used county roads and two-tracks occur in the area.	C
27	The plants grow in cracks in the rocks and flat areas at the edge of the cliffs on the south face (215 degrees aspect) above a creek, which is a willow-dominated, meandering, small stream. The rock appears to be basalt, and the plants do not grow on nearby cliffs with a different rock type. Where bare rock is not so abundant and the grassland vegetation extends to the edge of the cliffs, few plants are found. Most of the surrounding vegetation above the cliffs is characterized by sparse shrubs (mostly rabbitbrush and winterfat) with blue grama the common herbaceous species. Associated species growing in the cracks of rocks include *Stipa scribneri*, *Eriogonum jamesii*, and *Erigeron* spp.	Approximately 95 percent are fruiting and 5 percent flowering. Plants range in size from a few inches to 2 feet in diameter probably indicating numerous age classes. Linear occurrence extending about 1/2 mile. In relatively undisturbed habitat, in a landscape that is dominated by native plant communities and is relatively unfragmented.	Not reported.	A
Elliott 9066; pers. comm. Elliott 2004	Grassy slope and understory of *Pinus ponderosa* and *P. edulis* forest	Not reported.	Use of non-system roads were observed in 2004 that have impacted the occurrence.	E
Elliott 6728	*Bouteloua* spp., *Amelanchier* spp., *Pinus edulis*,and *Juniperus* spp.	Not reported.	Not reported.	E
Hartman 66135	Rocky outcrops and rocky ridge with Douglas-fir.	Not reported.	Not reported.	E
Hartman 66418	Volcanic rock.	Not reported.	Not reported.	E
Hartman 66488	Grassy slopes, coniferous covered tops.	Not reported.	Not reported.	E

Source I.D.	General Habitat Description	Element Occurrence Data	Management Comments	EO Rank
Hartman 66532	Pinyon/juniper with volcanic rock outcrops.	Not reported.	Not reported.	E
Hartman 66533, 66629, 66630	Rocky rim; limestone.	Not reported.	Not reported.	E
Elliott 11675; pers. comm. Elliott 2004	In a rocky montane meadow. Variable aspect; Slope: 0 to 25 degrees; dry soil; open. Much turning of the soil by rodents. In a grazing allotment with light grazing; elk grazing was most evident on 8/17/2003. Associated species: *Elymus elymoides*, *Artemisia frigida*, *Selaginella densa*, *Antennaria* spp., *Oxytropis* spp., *Festuca* spp., 40 percent vegetative, 60 percent fruiting.	Not reported.	In an active grazing allotment. Cattle grazing was minimal in 2003 on the ridge where the occurrence was found due to limited water availability. However, in September 2004 the permittee had placed range improvements (salt blocks) in the middle of this occurrence. This has resulted in heavy impacts to the occurrence. Many plants have been heavily utilized (up to 70 percent) and trampled by cattle. Attempts are underway to mitigate impacts at this location.	B
Holt 648	*Pinus edulis* woodland.	In fruit.	Not reported.	E
Holt 1145	Mixed conifer to aspen in open grassland.	In flower.	Not reported.	E
Flaig 3403	Not reported.	Not reported.	Not reported.	E
Flaig 3628	On north and south facing slopes.	Not reported.	Not reported.	C
Flaig 5518	In a stand of ponderosa pine above rocky outcrops on north facing slope in full shade.	Not reported.	Not reported.	C
Flaig 6238	On a disturbed slope.	Not reported.	Not reported.	E

Steppe Division, it is found on the margins of the Great Plains-Palouse Dry Steppe Province and the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province. Annual rainfall in areas inhabited by *N. lithophila* varies from 7 to 16 inches per year, much of which falls early in the growing season, with very little later in the summer (Carron 1990, Johnston personal communication 2002).

Neoparrya lithophila is found primarily on late-Tertiary volcanic substrates. These include dikes, lava flows, and igneous outcrops composed primarily of basalt or tuff (O'Kane et al. 1988, Carron 1990, Elliott 2000, Neely et al. 2001, Colorado Natural Heritage Program 2004). It is primarily distributed along the eastern margin of the San Juan Volcanic Area (O'Kane et al.1988). Tertiary volcanic substrates are widely distributed in south central and southwestern Colorado (Tweto 1979, Chronic 1980). Tertiary ash flow tuff and pre-ash flow volcanics underlie much of the eastern San Juan Mountains (**Figure 6**). At the type locality in Huerfano County, numerous dikes radiate from the Spanish Peaks where *N. lithophila* is found (Tweto 1979, Chronic 1980).

Neoparrya lithophila is also found on sedimentary rock derived from extrusive volcanics of the Dry Union Formation at Salida (**Figure 7**; Neely et al. 2001, Colorado Natural Heritage Program 2004). Hartman (personal communication 2002) and Elliott (personal communication 2004) report finding the species at two locations recently on limestone where leachates from volcanic material above were apparently affecting the soil chemistry. This observation suggests that *N. lithophila* is sensitive to some aspect of the soil chemistry that is soluble in water, as is *Sullivantia hapemannii* (Johnston personal communication 2002). This also suggests that *N. lithophila* might have a somewhat broader ecological amplitude (*sensu* Klinka et al. 1989) than previously believed.

Neoparrya lithophila is most commonly found growing on rock shelves or in cracks on steep, inaccessible volcanic cliffs and rock outcrops (**Figure 8** and **Figure 9**). Its affinity for this habitat gives the plant a large degree of natural protection at many locations. The habitat for *N. lithophila* at most locations is relatively stable and is not subject to frequent disturbance, although occurrences on the Dry Union Formation are disturbed by rapid erosion (**Figure 10**). The associated vegetation is typically sparse, and many plants have no other plant species nearby that might share rhizosphere resources. *Neoparrya lithophila* is typically found in full sun unless shaded by cliffs and rocks, as is often the case. In 2004, a very small occurrence (approximately 10 individuals) was found in Mineral County in the shade of *Pinus ponderosa* (ponderosa pine) (Flaig 5518, Rio Grande National Forest). Another occurrence in Chaffee County occurs partly in the shade of *P. ponderosa* (Elliott 9066). It appears that this habitat is highly atypical, but further survey work is needed to determine the suitability of these habitats for *N. lithophila*. At locations in Chaffee and Fremont counties, *N. lithophila* is found in grasslands on sloped sites were it is not naturally protected (**Figure 11** and **Figure 12**).

Elevation documented in Colorado Natural Heritage Program element occurrence records and specimen labels ranges from 7,280 to 9,800 feet, but *Neoparrya lithophila* is most commonly found between 7,500 and 8,500 feet in elevation. Ryke et al. (1994) report elevations as low as 6,700 feet. Elliott (2000) found occurrences between 7,600 to 9,800 feet. Neely et al. (2001) includes 7,000 to 10,000 feet as the elevation range.

The most common habitats for *Neoparrya lithophila*, rock shelves and cracks in cliff faces, are arid and chronically water-stressed. This, combined with the high degree of insolation, exposure, and dark color of the surrounding rock, certainly creates an extremely hot and dry microclimate in the canopy of these plants. Little to no soil is available to hold water for most plants in some of the large occurrences of this species, which would seem to exacerbate the stressfulness of this habitat. However, roots probing into cracks in the rock might access significant amounts of trapped moisture that could help the species to cope with the hostile aridity above the surface. Bird droppings and leachate from the weathering of the volcanic substrate may actually provide a rich supply of nutrients for *N. lithophila*. Aeolian deposition of dust, soil, and organic matter may further contribute to the mineral and organic nutrition of these plants.

Although *Neoparrya lithophila* is found on all aspects, reports in element occurrence records suggest that it favors north slopes (Neely et al. 2001, Colorado Natural Heritage Program 2004). These sites are nonetheless still quite xeric. It is possible that the species is not responding to moisture or insolation, but to the availability of microsites, which may be a function of differential weathering of the rocky substrate or other secondary effects of aspect. *Neoparrya lithophila* typically grows on very steep to vertical slopes. It is

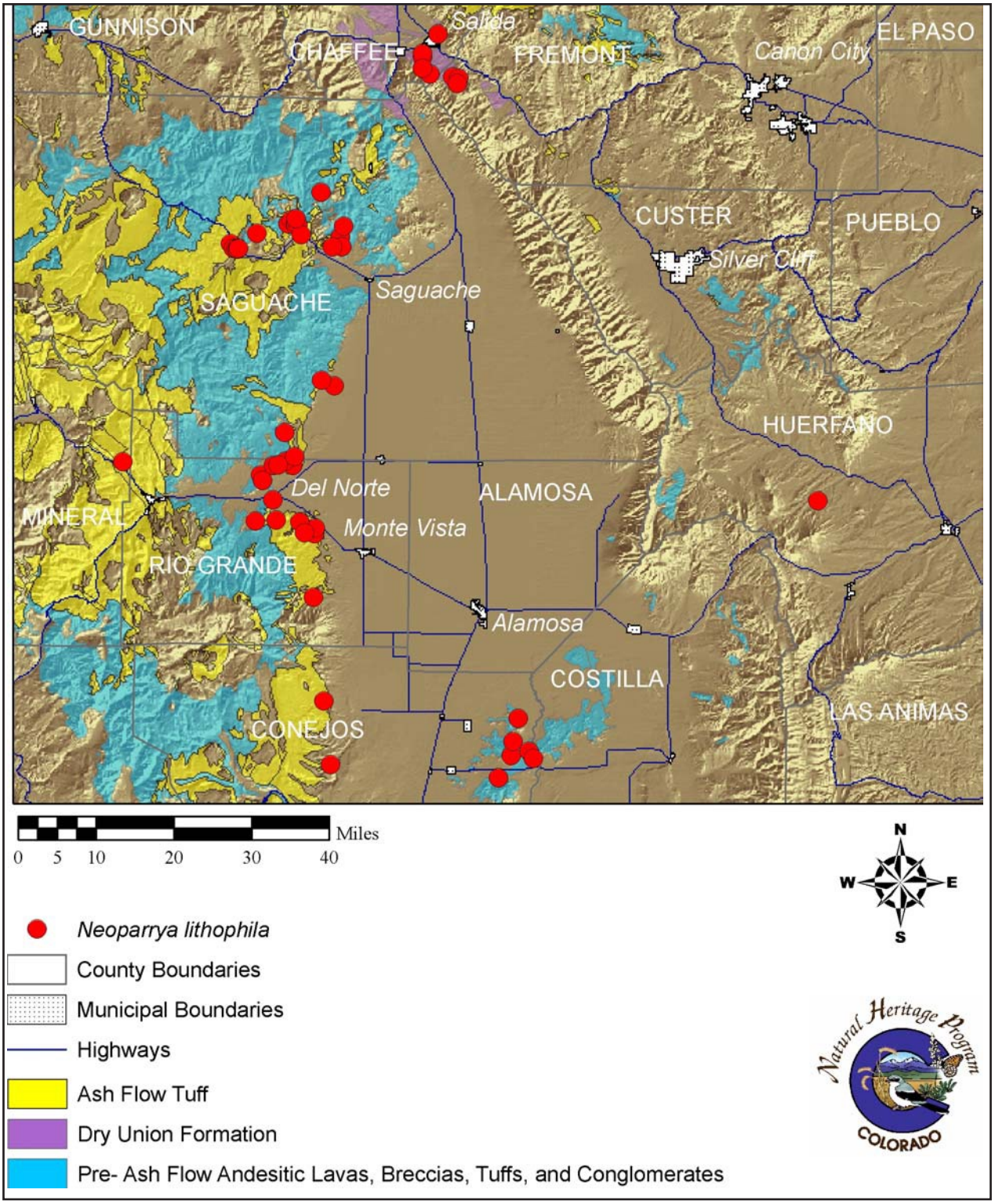

Figure 6. The distribution of principal geologic strata (after Tweto 1979) in relation to the known occurrences of *Neoparrya lithophila*.

Figure 7. Wasting slopes of the Dry Union Formation in Chaffee County (EO 9). *Neoparrya lithophila* is found on the colluvial slopes below the escarpment at this location (see **Figure 10**). Photograph by Brian Elliott, USFS botanist, San Isabel National Forest.

Figure 8. Typical habitat of *Neoparrya lithophila* at Farisita Dike. Photograph provided by Terri Schulz.

Figure 9. Habitat of *Neoparrya lithophila* at Farisita Dike. Photograph provided by Terri Schulz.

Figure 10. An unusual occurrence of *Neoparrya lithophila* on a steep wasting slope, where rapid erosion has left plants standing on pillars of soil. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

Figure 11. Habitat of *Neoparrya lithophila* at Bear Creek (Elliott 11675). The bare ground in the lower right is the result of the placement of a salt block encouraging cattle to graze at the site (Elliott personal communication 2004). Photograph by Brian Elliott, USFS botanist, San Isabel National Forest.

Figure 12. Close-up photograph of habitat of *Neoparrya lithophila* at Bear Creek (Elliott 11675) on the San Isabel National Forest. Photograph by Brian Elliott, USFS botanist, San Isabel National Forest.

possible that it is limited to these sites by herbivore impacts and competition with other species that would occur on more level substrates.

Most known occurrences of *Neoparrya lithophila* occur on the eastern edge of the San Juan Volcanic Area (Hartman 1984). This feature is approximately 15,000 square kilometers and includes all of the San Juan Mountains. It is comprised principally of basalt and other volcanics deposited in the Tertiary period. *Neoparrya lithophila* is also found in Chaffee and Fremont counties, Colorado, at one undisclosed location in New Mexico (Hartman personal communication 2002), and at the type locality on the Spanish Peaks in Huerfano County (Farisita Dike).

Habitat for *Neoparrya lithophila* is not particularly facile and probably varies little in its extent from year to year. Modern human impacts within its range have done little to diminish the extent of habitat because they have not been particularly destructive. The slow erosion and weathering of the volcanic rocks on which it persists are the primary arbiters of change in the habitat of *N. lithophila* at present. As the tertiary volcanics of the eastern San Juans and the Spanish Peaks continue to erode, new substrates will be revealed as old ones disappear.

Many observations note areas of apparently suitable habitat adjacent to occurrences of *Neoparrya lithophila* that are not occupied (Colorado Natural Heritage Program 2004). In at least one case the lower parts of a dike were not occupied, and the observers speculated that these portions of the dike were below the elevational limit of the species. Much of the San Luis Hills in Saguache County, Colorado appear suitable for *N. lithophila*, but the species is inexplicably absent from many locations (Rondeau et al. 1998). This suggests that *N. lithophila* has physiological limitations precluding its immigration to these locations.

Reproductive biology and autecology

Neoparrya lithophila is a slow-growing, long-lived species (Theobald et al. 1964). Hartman (personal communication 2002) speculates that plants he has observed have lived for tens of years, and possibly more than 100 years. Long life spans are not uncommon among the western Apiaceae, particularly among those in arid or barren habitats. Demographic models for *Lomatium bradshawii* suggest that individuals in a population of 2,000 plants have a 90 percent probability of surviving for 100 years (Parenti et al. 1993). Monitoring data from Farisita Dike (Carpenter 1992) also suggest that *N. lithophila* is long-lived.

In the CSR (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), characteristics of *Neoparrya lithophila* most closely approximate those of a stress-tolerant-ruderal species. Attributes of *N. lithophila* typical of stress-tolerators include its long life span, adaptations to aridity, and apparent poor competitive ability. However, it can produce copious quantities of seed (Carpenter 1992, Carpenter personal communication 2004) and apparently has some tolerance of disturbance, which are strategies employed by ruderal strategists under this model.

As with many other members of the Apiaceae, *Neoparrya lithophila* is probably self-fertile, although there have been no investigations to confirm this. However, it is also protogynous, which is a type of dichogamy (the maturation of male and female organs of a flower at different times) (Hartman personal communication 2002). In the protogynous Apiaceae, the styles are well exserted from the flower several days before the anthers are evident. Thus, although a flower may be self-fertile, it is functionally female until the anthers dehisce, and it will tend to outcross. The timing of the maturation of the male and female organs in the flowers is usually synchronized throughout a plant so that pollen from other flowers on the same plant does not tend to reach the stigmas.

An accepted feature of the Apiaceae is the high degree of floral uniformity throughout the family (Bell 1971). Plants with very little floral specialization are considered 'promiscuous plants' because they utilize unspecialized, generalist pollinators as pollen vectors (Grant 1949, Bell 1971). Because this characterizes species throughout the Apiaceae family, this breeding system probably evolved in the early ancestors of our modern taxa and has been maintained as a relatively fixed character ever since (Bell 1971). Reliance on a broad suite of pollinators for pollinator services probably buffers promiscuous plants from population swings of any one pollinator (Parenti et al. 1993). Although most species in the Apiaceae have unspecialized flowers, some species appear to be developing a weakly specialized flower-pollinator interaction (Bell 1971, Lindsey and Bell 1985). Thus, the floral biology of *Neoparrya lithophila* must be investigated to ensure that conservation actions on its behalf include the protection of its pollinators.

Neoparrya lithophila blooms from May to early July and sets fruit from late June through September (Spackman et al. 1997, Neely et al. 2001). Plants are green and visible through September. *Neoparrya lithophila* reproduces by seeds that are shed in late summer. Young plants with poorly developed root systems are probably more vulnerable to desiccation than mature plants. Thus, the periodicity of successful recruitment may coincide with periods of one or several wet years during which they can become established.

Reproductive effort of *Neoparrya lithophila* was assessed at Farisita Dike by counting the number of flowering stems per plant. The average number of stems per plant varied from year to year, with nearly twice as many per plant in 1992 as in 1991 (**Table 5**). The number of flowering stems per plant ranged from 0 in juvenile/non-reproductive plants to 161 on a large individual in 1992. Some small individuals remained vegetative in 1991. Observations at Farisita Dike show that *N. lithophila* is iteroparous (a polycarpic perennial capable of producing flowers over many years). The number of seeds per flowering stem was evidently not determined, which would permit an estimation of fecundity. In favorable years, *N. lithophila* was observed to produce copious quantities of seed at Farisita Dike (Carpenter personal communication 2004).

Table 5. Summary of demographic data from Farisita Dike occurrence of *Neoparrya lithophila* from 1990 through 1992 (Carpenter 1992).

	1990	**1991**	**1992**
Average number of flowering stems per plant	16.49	12.36	21.92
Average size (cm^2)	209.19	210.80	252.98

On December 5, 1991, a seed germination experiment was established at Farisita Dike to investigate seed viability and longevity. Thirty bags, each containing 100 seeds that had been collected in 1990, were placed on the surface under the snow and weighted down with fist-sized rocks (West 1991). It was intended that these bags would be observed during the monitoring visits and would be tested using standard seed viability tests (Carron 1990). The bags were to be retrieved periodically to test the viability of the seeds over time. However, there appear to be no data available on the results of this experiment, and it is not known if it was completed (Carpenter personal communication 2004, Schulz personal communication 2004).

Long distance dispersal capabilities are typical of plants that occupy patchy environments (Barbour et al. 1987). However, the seed of *Neoparrya lithophila* is not winged and appears less adapted to long distance dispersal by wind than many other members of the Apiaceae. There have been no investigations into the dispersal mechanisms employed by *N. lithophila*. Hartman (personal communication 2002) speculates that it is bird dispersed. Birds would be an excellent dispersal vector for *N. lithophila* since the high and rugged rock outcrops it inhabits are excellent perches. The oils within the seeds may render them indigestible to the birds, causing them to be defecated elsewhere. The fruits are also quite sticky, which could facilitate dispersal on mammals or birds by sticking to their feet or bodies (Johnston personal communication 2002).

Given the large seed size of *Neoparrya lithophila*, it is likely that seeds are able to survive in the seed bank for more than one season, since larger seeds are typically long-lived (Baskin and Baskin 2001). In many locations, where the plants are growing on cliffs in cracks in the rock, there is very little soil in which a seed bank could potentially reside, and few safe sites in which seeds can lodge and germinate. Because the probability of successful immigration is necessarily low in these habitats, species with perennial life histories are naturally favored.

Neoparrya lithophila shows very little phenotypic plasticity, but some plants appear more robust than others (Hartman personal communication 2002). This may be a function of available resources and microsite attributes. As is typical of the Apiaceae, the leaf characters of *Aletes* and *Neoparrya* are somewhat variable and difficult to describe (Theobald et al. 1964). The bractlets of the involucels are sometimes minutely scaberulous on the margins (Theobald et al. 1964), but this is not a particularly diagnostic characteristic.

Hartman (1984) and Johnston (personal communication 2002) report evidence for ecotypic variation in *Neoparrya lithophila*. Johnston (personal communication 2002) reports finding occasional plants with larger, lax leaves than typical of the species (referred to as the "shade form"). Hartman (1984) notes that leaf segments tended to be slightly narrower in the western occurrences, and the plants appeared to be smaller.

There have been no studies of the mycorrhizal relationships in *Neoparrya lithophila*. Hartman (personal communication 2002) speculates that *N. lithophila* is a host for mycorrhizal fungi, but he knew of no research that would infer the nature of any symbioses involving *N. lithophila*.

Hybridization is extremely rare in the Apiaceae (Heywood 1993). No evidence of hybridization has been documented in *Neoparrya lithophila*, and there are no other members of the Apiaceae family associated with *N. lithophila* that could provide the opportunity for hybridization (Hartman personal communication 2002).

Demography

Neoparrya lithophila occurs in naturally small, isolated occurrences. The amount of geneflow is unknown, but because distances of many miles separate many occurrences it can be assumed that geneflow is limited. Endemic and rare taxa often have low genetic variability (Hamrick and Godt 1990, Karron 1991). They also tend to have greater rates of self-pollination and inbreeding (Inoue and Kawahara 1990, Karron 1991).

The level of genetic variability in *Neoparrya lithophila* has not been measured. However, it has been measured in one of its close relatives, *Aletes humilis*, which has a similar population structure to *N. lithophila*, consisting mainly of widely scattered occurrences on isolated rock outcrops. The genetic diversity of *A. humilis* is as high as its more common congener and reputed ancestor, *A. acaulis* (Linhart and Premoli 1993). No readily observable effects of inbreeding depression have been documented in *N. lithophila*.

No Population Viability Analysis (PVA) has been performed for *Neoparrya lithophila*. Apparently there has never been a PVA of any member of the Apiaceae from which inferences could be drawn for this report.

Many life history parameters remain unknown in *Neoparrya lithophila*. Of particular value would be information on seeds and recruitment. Seed production, seed longevity, seed dormancy, and variables controlling these parameters would help to reveal potential bottlenecks in the survival of *N. lithophila* (Colorado Natural Heritage Program 2004). Longevity is also unknown, yet critical for understanding the demography of this species.

Basic life history parameters can be inferred from monitoring data obtained at Farisita Dike (EO 1). Plants observed at Farisita Dike ranged in size from 1 cm^2 to 1,698 cm^2 (Carpenter 1992). The size of individual plants generally changed slowly, although some rapid growth (primarily among younger individuals) was observed (**Figure 13**). In general, growth is slow, suggesting that large plants are very old. The canopy size of some individuals decreased from 1990 to 1991, suggesting that biomass production was limited by growing conditions in 1991. For a hypothetical life cycle graph for *Neoparrya lithophila* based on the data of Carpenter (1992) please see **Figure 14**.

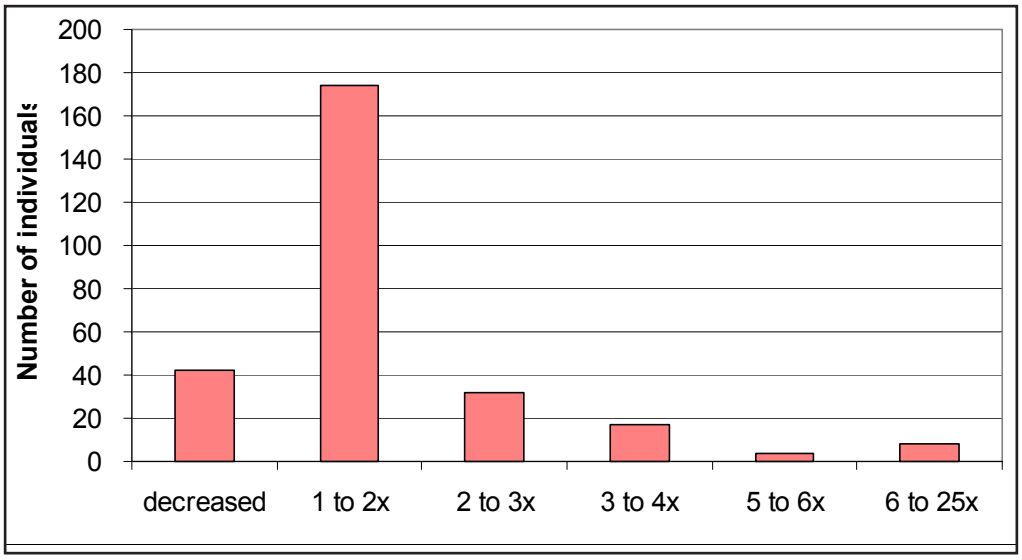

Figure 13. Histogram of change in plant size at Farasita Dike between 1990 and 1992.

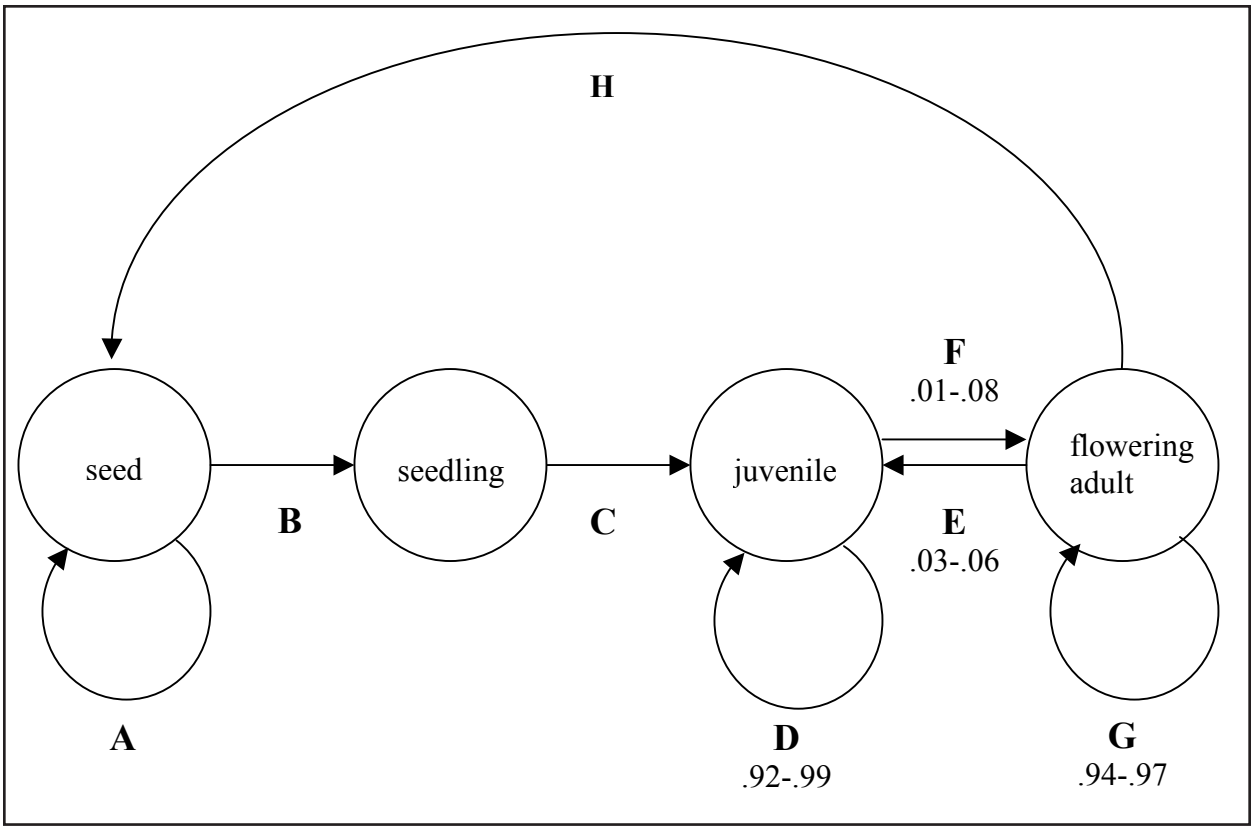

Figure 14. Hypothetical life cycle graph (after Caswell 2001) for *Neoparrya lithophila*. The probability of transition A is not known, although an experiment was initiated in 1991 to attempt to determine seed viability and longevity (West 1991). The probabilities of transitions B and C are unknown. The duration of the juvenile stage is not known, but plants can remain in the juvenile stage for multiple years (D) (probability of remaining a juvenile was .92 in 1992 and .99 in 1991) (Carpenter 1992). The probability of becoming a flowering adult in 1991 was only .01 (likely due to drought) while in 1992 the probability was .08 (F) (Carpenter 1992). Some small individuals that had flowered in one year remained vegetative in a subsequent year (E) (probability of becoming a juvenile from a flowering adult was .06 in 1991 and .03 in 1992) (Carpenter 1992). *Neoparrya lithophila* is clearly a polycarpic perennial (G) (probability of remaining a flowering individual was .94 in 1991 and .97 in 1992) (Carpenter 1992). Given a probable slow growth rate and the large size of some individuals, plants probably survive for many tens of years or perhaps 100 years as flowering adults (G) (Carpenter 1992, personal communication. Hartman 2002). Fecundity has not been measured (H), but this could be estimated by determining the number of seeds produced by an average flowering stem as described in Carron (1990).

The probability of dispersal of seeds and other propagules decreases rapidly with increasing distance from the source (Barbour et al. 1987). Thus, long distance dispersal events are rare. Pollinator-mediated pollen dispersal is largely limited to the flight distances of pollinators (Kearns and Inouye 1993). Due to the formidable physical limitations to dispersal of seeds and pollen between occurrences, there is probably very little geneflow between occurrences of *Neoparrya lithophila*. The flat areas surrounding the rock outcrops inhabited by *N. lithophila* undoubtedly act as sinks when seeds are blown or washed onto these areas.

As a habitat specialist, population sizes of *Neoparrya lithophila* are naturally limited by the availability of habitat. The volcanic rock outcrops and cliffs on which *N. lithophila* lives are small and insular. Within an area of suitable habitat, the availability of microsites suitable for *N. lithophila* is also limited, in most places precluding the development of a large population. Thus, the distribution and physiognomy of habitat for *N. lithophila* imposes constraints on population growth at a variety of scales.

Community ecology

Observations on the plant community ecology of *Neoparrya lithophila* are limited to qualitative observations. These have included notes on the biotic and abiotic associations with *N. lithophila* such as associated species and various natural history observations describing slope, aspect, geology, and soil.

Associated vegetation is markedly different than that surrounding the rock outcrops on which *Neoparrya lithophila* is found. Many of the species associated with *N. lithophila* are very common, although another rare plant species, *Oreocarya weberi*, sometimes co-occurs with *N. lithophila* (Colorado Natural Heritage Program 2004). *Neoparrya lithophila* is associated primarily with shrubs and herbaceous species, but it sometimes occurs with *Pinus edulis*, *P. ponderosa*, or *Pseudotsuga menziesii*. Shrubby associates include *Rhus trilobata*, *Cercocarpus montanus*, and *Ribes cereum*. Other species include *Eriogonum jamesii*, *Opuntia polyacantha*, *Echinocereus triglochidiatus*, *Heterotheca villosa*, and *Yucca glauca*. Several grass species commonly co-occur with *N. lithophila* including *Koeleria macrantha*, *Chondrosum gracile*, *Oryzopsis micrantha*, *O. hymenoides*, *Muhlenbergia filiculmis*, *Stipa scribneri*, and *Festuca* spp. (Colorado Natural Heritage Program 2004). Hartman (1984) also noted *Artemisia dracunculus* and *A. frigida* as common associates. At Farisita Dike, Weber (1958) noted *Pinus edulis*, *Leptodactylon pungens*, *Hymenoxys richardsonii*, and *Gutierrezia sarothrae*. Lichens are also frequently noted as a major component of the plant community with *N. lithophila* (Rondeau et al. 1998). In areas surrounding occurrences of *N. lithophila*, frequently cited dominant species include *Chrysothamnus greenei*, *Sarcobatus vermiculatus*, and *Krascheninnikovia lanata* (Kettler et al. 2000, Colorado Natural Heritage Program 2004). Please see **Table 4** for all associated species documented in element occurrence records.

The vegetation is often very sparse where *Neoparrya lithophila* grows, and it is often the dominant (or only) plant species present, particularly on very steep or vertical rock faces or ridgetops. *Neoparrya lithophila* is known from a variety of plant communities. It has often been reported from Pinyon-juniper, *Bouteloua-Artemisia frigida* grassland, ponderosa-pinyon pine forests, and rocky ridges with *Pseudotsuga menziesii* (Elliott 2000, Neely et al. 2001).

Grazing and browsing of *Neoparrya lithophila* have been documented. Livestock grazing has been reported as heavy at two occurrences (EO 2 and Elliott 11675) (**Figure 15**). At the Upper Saguache Guard Station/Taylor Canyon occurrence (EO 2), inflorescences had been selectively browsed (Colorado Natural Heritage Program 2004). Deer and elk feces were also observed in the area, suggesting that this plant is of possible nutritional value to these species. Elk grazing was also apparent at Bear Creek (Elliott 11675; Elliott personal communication 2004). Soil disturbance by fossorial rodents was also observed at Bear Creek (Elliott personal communication 2004). The inaccessibility of most populations to deer and elk ensures that *N. lithophila* is seldom eaten by them. Heavy grazing of bunchgrasses was observed at Farisita Dike in 1991 (West 1991), but grazing of *N. lithophila* was not noted. Johnston (personal communication 2002) found umbels placed on a rock as though to dry, apparently by a small mammal. Horses and cattle have also reportedly grazed this species, but this is also limited by the inaccessibility of most plants.

At Farisita Dike, two plants were observed in 1990 and one in 1992 that appeared "sick" (Carpenter 1992). However, there are no details available on the nature of the illness befalling these individuals. There are no other reports of parasites or disease in *Neoparrya lithophila*.

There is no information on competitors for biotic and abiotic resources with *Neoparrya lithophila*. If competitive interactions are important in the autecology of *N. lithophila*, some of the associated species cited above are the most probable competitors. However, stress tolerant species *sensu* Grime (2001) do not typically need to be highly competitive because highly competitive species are not capable of withstanding the chronic stress regime to which the stress-tolerant species are supremely adapted. Thus, they typically do not share the same resource pool with species such as *N. lithophila*.

CONSERVATION

Threats

Numerous reports, observations, and opinions of experts show that there are several threats to the persistence of *Neoparrya lithophila*. In order of decreasing priority these are off-road vehicle use, grazing, other recreation activities, mining, timber harvest, effects of small population size, residential and commercial development, right-of-way management, exotic species invasion, global climate change, and pollution. These threats and the hierarchy ascribed to them are somewhat speculative, and more complete

Figure 15. Grazing of *Neoparrya lithophila* at Bear Creek on September 14, 2004 (Elliott 11675). Up to 70 percent utilization of plants by cattle was observed at this site. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

information on the biology and ecology of this species may elucidate other threats. Assessment of threats to this species will be an important component of future inventory and monitoring work. Please see the following sections for specific treatments of these threats to habitat and individuals and additional threats from exotic species and over-utilization.

In general, concentrated use in occurrences is likely to threaten *Neoparrya lithophila*. The lack of information on this species and the lack of occurrence knowledge by land owners or administrators is a threat since land management decisions do not often give consideration to the needs of this species. Many occurrences of *N. lithophila* are naturally isolated, which affords many occurrences ample protection from human and grazing impacts (Carron 1990, Colorado Natural Heritage Program 2004). Overall, the greatest threats to *N. lithophila* are those that result in the disturbance of its habitat (Kettler et al. 2000, Colorado Natural Heritage Program 2004). As a long-lived, stress tolerant, slow-growing perennial, it is likely that this species would not be particularly resilient when its habitat is disturbed or altered.

Influence of management activities or natural disturbances on habitat quality and individuals

Illegal off-road vehicle use has impacted at least one occurrence of *Neoparrya lithophila*. Non-system (user-created) roads have cut swaths through an occurrence on Methodist Mountain (Elliott 9066) on the San Isabel National Forest, causing habitat fragmentation. Vehicle use of this area has also resulted in direct impacts to individuals (Elliott personal communication 2004). Some user-created roads have impacted limited portions of the occurrence at Elephant Rocks (EO 8), but these impacts may have been ameliorated by current management and land status designation (Schulz personal communication 2004). Nine records (EO 15, 20, 21, 22, 24, 26, Elliott 9066, Holt 648, and Holt 1145) indicate the presence of roads through occurrences or in their close proximity. Two of these (EO 15 and Elliott 9066) are on USFS land (Spring Branch RNA on the Rio Grande National Forest and San Isabel National Forest, respectively) (**Figure 16**).

Figure 16. Impacts to *Neoparrya lithophila* resulting from a road that bisects the occurrence at Methodist Mountain (Elliott 9066). A few plants have colonized the roadcut. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

Neoparrya lithophila apparently has some forage value to cattle and horses as well as native species possibly including deer and elk, and plants in pastures will likely be eaten (**Figure 15**). It appears that most occurrences are either inaccessible to livestock or are on the uplands where livestock will not frequently venture due to lack of water (Elliott personal communication 2004). Grazing has limited impacts on most occurrences of *N. lithophila* because it often grows on inaccessible rock outcrops with little forage value (Neely et al. 2001). However, range improvements (placement of salt blocks within an occurrence) at the recently discovered occurrence at Bear Creek (Elliott 11675 on the San Isabel National Forest) have been observed to result in heavy utilization of some plants (up to 70 percent) and trampling (Elliott personal communication 2004). Grazing occurs near most occurrences of *N. lithophila*. Six of the ten occurrences of *N. lithophila* on USFS land are within active grazing allotments (**Table 6**). In general, occurrences in Fremont and Chaffee counties, where occurrences tend to be more easily accessible to livestock, are probably more threatened by grazing than most occurrences in Saguache, Rio Grande, and Huerfano counties.

Recreational use of areas inhabited by *Neoparrya lithophila* has the potential to negatively impact occurrences. Campfire rings and other recreational impacts have been observed within an occurrence of *N. lithophila* in Chaffee County (Elliott 9066 on the San Isabel National Forest) (**Figure 17**). At this location the campfire ring and associated impacts (where vehicles had driven over plants) clearly resulted in some attrition. Of minor concern is the potential for impacts from rock climbing on individual occurrences. Some human impacts have been observed at Elephant Rocks (EO 8, located in part on the Rio Grande National Forest) including campsite establishment, campfire ring proliferation, trampling, and trash (O'Kane 1986). Extensive trash and other plants trampled by humans were observed at the Rock Creek Gaging Station in Rio Grande County (EO12; Colorado Natural Heritage

Table 6. Grazing allotments and current grazing activity for known occurrences of *Neoparrya lithophila* on national forests in USDA Forest Service Region 2 (from Webb 1996, Poe personal communication 2004, White personal communication 2004). Source I.D. is Colorado Natural Heritage Program element occurrence number unless otherwise noted.

Source I.D.	Location	National Forest	Allotment	Activity
6	660 Road	Rio Grande	Indian Head/Natural Arch	Active/Closed
8	Elephant Rocks	Rio Grande	Indian Head	Active
15	Spring Branch Research Natural Area	Rio Grande	Non-allotment	—
25	East Butte	Rio Grande	Indian Head	Active
Elliott (9066)	Methodist Mountain	San Isabel	Non-allotment	—
Hartman (66532)	Poison Gulch Road	Rio Grande	Klondyke	Active
Hartman (66533, 66629, 66630)	Spring Gulch Rimrock	San Isabel	Bear Creek	Active
Elliott (11675)	Bear Creek	San Isabel	Bear Creek	Active
Holt (1145)	Rainbow Trail	San Isabel	Non-allotment	—
Flaig (5518)	Rio Grande Pallisades	Rio Grande	Pallisades WLA	Not active

Figure 17. Damage to individuals and habitat of *Neoparrya lithophila* were observed at Methodist Mountain (Elliott 9066) resulting from high-impact camping. *Neoparrya lithophila* can be seen in center foreground. Photograph provided by Brian Elliott, USFS botanist, San Isabel National Forest.

Program 2004). These impacts affected a small part of the occurrence at this location; most of the plants remained protected by their inaccessibility.

No mining currently takes place within the known occurrences of *Neoparrya lithophila* on USFS lands or elsewhere. Mining has occurred historically at two locations (EO 18 and 26, both on Bureau of Land Management property) (Colorado Natural Heritage Program 2004). At one location (EO 26), it is appears that mining impacted a portion of the occurrence.

At the behest of the Healthy Forest Initiative, forest thinning activities may begin in the near future. These may include pinyon-juniper stands within and adjacent to occurrences of *Neoparrya lithophila* and are potentially deleterious for several reasons. In Chaffee County, timber extraction on sites underlain by the Dry Union Formation has the potential to destabilize fragile soils and to greatly enhance erosion. Direct impacts to plants are also possible, as is the introduction of exotic species.

Currently, there is no evidence of direct impacts from residential development on any occurrence of *Neoparrya lithophila*. However, indirect impacts from increased visitation might be substantial in some occurrences in the future (Kettler et al. 2000, Colorado Natural Heritage Program 2004). The proliferation of roads and disturbance from construction and utility installation resulting from residential and commercial development may fragment habitat and encourage the spread of weeds in the habitat of *N. lithophila*. The barrier effect of roads is known to have broad demographic and genetic consequences, which are reviewed in Forman and Alexander (1998).

Occurrences within rights-of-way are highly susceptible to impacts from road maintenance such as mowing, spraying for weeds, and road widening. Threats to roadside occurrences are ongoing and will be difficult to fully ameliorate. Plants within 23 feet of the pavement (or 15 feet, depending on the size of the mower used) may be mowed repeatedly through the growing season (Powell personal communication 2003). There is at least one occurrence on the San Isabel National Forest (Elliott 9066) in which plants occur adjacent to a USFS road and are also found on the roadcut (**Figure 16**).

Global climate change is likely to have wide-ranging effects in the near future. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. Temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *Neoparrya lithophila* is already xeric, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts. Other models predict increased winter snowfall (e.g., Giorgi et al. 1998), which has other implications for *N. lithophila*. Increased snowfall could delay the onset of the growing season if persistent snow covers occurrences late into the spring.

Atmospheric nitrogen deposition (of both organic and inorganic forms) is increasing worldwide. Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses.

Interaction of the species with exotic species

Exotic plant species (weeds) are not common in the habitat for *Neoparrya lithophila*, but many element occurrence records note the presence of exotic species nearby. Hartman (personal communication 2002) has noted the presence of cheatgrass (*Bromus tectorum*) within unspecified occurrences of *N. lithophila*. It has also been documented at Farisita Dike (EO 1), where it is abundant on the top of the dike (Neely 1986) and at Elephant Rocks (EO 15, Rio Grande National Forest). The impact of this species on *N. lithophila* is not known but warrants further study. Alterations of the fire regime that cheatgrass might cause within occurrences of *N. lithophila* are of particular concern. Because fire is probably an infrequent event in *N. lithophila* occurrences, it is probably not particularly tolerant of fire. *Cirsium arvense* has also been documented with *N. lithophila* at Farisita Dike (Neely 1986). Other exotic species noted in areas adjacent to habitat for *N. lithophila* include *Salsola tragus*, *Kochia scoparia*, and *Hyoscyamus niger* (Rondeau et al. 1998, Kettler et al. 2000). It is not known what threat, if any, these species present to *N. lithophila*. Because new exotic species are arriving all the time, vigilance in monitoring for their impacts is crucial. It is possible that an insipient weed could favor the habitat for *N. lithophila* when it arrives, and require costly management efforts for its control.

Threats from over-utilization

Many species in the Apiaceae family have immense commercial value and are widely used and cultivated. Members of this family have many volatile compounds in their vegetative parts and fruits. Some of these compounds are toxic while others have important culinary and medicinal applications. Numerous taxa in the Apiaceae contain acetylenic compounds of unknown toxicity risk (Burrows and Tyrl 2001). The toxicity of *Neoparrya lithophila* has not been investigated.

Currently, there is no commercial use of *Neoparrya lithophila*, but there is potential for over-utilization if it becomes popular in the herb trade. Another member of the Apiaceae, *Ligusticum porteri*, has become popular and is commonly collected in the wild. This practice has had serious negative impacts to many wild populations (NatureServe 2002). Like *N. lithophila*, *L. porteri* is a long-lived perennial. Peterson et al. (1983) did not recommend listing of *N. lithophila* as part of the International Convention on Trade in Threatened and Endangered Species because no commercial uses had been documented for it.

Conservation Status of the Species in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

There are no reports that suggest that any particular occurrence of *Neoparrya lithophila* is in decline or has been extirpated due to human or natural influences on USFS land or elsewhere. From its re-discovery in 1957 to 1980, the occurrence at Farisita Dike remained stable (Peterson et al. 1984). Monitoring data gathered by the Nature Conservancy at Farisita Dike from 1990 to 1994 also do not suggest population decline. Although some fairly rigorous data on distribution have been amassed (Rondeau et al. 1998, Elliott 2000, Kettler et al. 2000, Colorado Natural Heritage Program 2004), these are largely qualitative or include rough population estimates. In addition, most occurrences have not been visited since their discovery to re-assess their status.

There is evidence that off-road vehicle use and grazing have resulted in declines of two occurrences on Forest Service and on the San Isabel National Forest (Elliott 9066 and Elliott 11675), and it appears likely that other occurrences on Bureau of Land Management land have incurred losses as a result of human activities as well.

Do habitats vary in their capacity to support this species?

Habitats vary greatly in their capacity to support *Neoparrya lithophila*. Sites with suitable north-facing rock exposures are more likely to harbor robust occurrences than sites with other aspects. The underlying ecological reasons for why some habitats support large occurrences while others with large patches of apparently suitable habitat support small occurrences are not known.

Vulnerability due to life history and ecology

Neoparrya lithophila is less vulnerable to the vagaries of demographic or environmental stochasticity than other species with similar suites of habitat specificity, life history, and ecological requirements. Rare plants are often habitat specialists; this can be of great benefit or of great detriment to a species depending on the utility of its habitat to human interests. Most habitat for *N. lithophila* is both inaccessible and marginally useful to people, and overall the area inhabited by *N. lithophila* remains sparsely populated at present. The habitat for *N. lithophila* in the strict sense has not declined, although the shrublands surrounding the rock outcrops and cliffs on which the plants reside have declined greatly in some areas (Kettler et al. 2000). Habitat quality has declined on two known occurrences on USFS land (Elliott 9066 and 11675). As a long-lived, stress-tolerant perennial, *N. lithophila* is buffered somewhat from the effects of environmental stochasticity such as drought.

Small population size may result in inbreeding depression in some occurrences of *Neoparrya lithophila*. The minimum viable population size is not known, but even small populations by the standards of the 50/500 rule of Soulé (1980) may still be viable and of conservation importance. The Colorado Natural Heritage Program considers populations of *N. lithophila* containing 10 or more plants as viable, but this threshold will be revised when the minimum viable population size is determined. The viability of two occurrences observed by Flaig (3628 and 5518, the latter on the Rio Grande National Forest) is questionable.

Evidence of populations in Region 2 at risk

Nine occurrences are within areas designated for the protection of biological resources (**Table 1**). One occurrence is found within the Spring Branch RNA on the Rio Grande National Forest where current objectives and management prescriptions are likely to favor its

persistence (Carsey 1996). Six occurrences are found on three BLM areas of critical environmental concern (Elephant Rocks, San Luis Hills, and Rio Grande River Corridor) where they benefit from current management. The Farisita Dike Preserve, which is owned by The Nature Conservancy, was established to protect this species. The Elephant Rocks occurrence is included within a Colorado state natural area, where it benefits from voluntary agreements with landowners to protect the unique natural resources of this site (Colorado State Parks 2004).

Although *Neoparrya lithophila* is relatively secure at present, it remains vulnerable due to its habitat specificity and high level of endemism, the small number of occurrences, and the high degree of isolation of individual occurrences. Certain types of human activities could easily extirpate or imperil one or more occurrences of this species by disturbing its habitat.

Some occurrences on USFS land and elsewhere are at risk from impacts as a consequence of land management. Despite protective land status designations, user impacts to the Elephant Rocks occurrence (EO 8, Rio Grande National Forest) from trampling and careless behavior place a portion of the population at risk. A portion of this occurrence has been impacted by non-system roads (Schulz personal communication 2004).

Grazing is a minor risk to most populations of *Neoparrya lithophila*. As observed at Farisita Dike (EO 1), 10 to 20 percent of plants in some occurrences are accessible to horses and cattle. However, the general inaccessibility to cattle and horses leaves them mostly unaffected by livestock grazing. The occurrence at Bear Creek (Elliott 11675, San Isabel National Forest; Elliott personal communication 2004) is accessible to cattle and is found within an active grazing allotment (White personal communication 2004). This occurrence appears to have incurred greater negative impacts resulting from land management than any other known occurrence.

Residential and commercial development is occurring throughout the range of this species, and there are occurrences within one mile of new housing developments. Four occurrences on private land (EO 6, 9, 17, 23) are at some risk from possible future development, at least in part. These four occurrences include approximately 8,700 individuals on private land, which represents approximately one sixth of the known population. Habitat fragmentation resulting from development and the construction of roads and utilities could result in impacts to many occurrences and has already impacted some on private and BLM property. Development might also negatively impact some of the generalist pollinator species on which *Neoparrya lithophila* depends by reducing nectar resources in the area. New exotic species are arriving constantly, and it may be only a matter of luck that the habitat for *N. lithophila* has not already been substantially invaded by exotics.

Management of the Species in Region 2

Implications and potential conservation elements

Desired environmental conditions for *Neoparrya lithophila* include sufficiently large areas where the natural ecosystem processes on which it depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a satisfactory degree of ecological connectivity between occurrences to provide corridors and other nectar resources for pollinators. Given the current paucity of information on this species, it is unknown how far this ideal is from being achieved. It is possible that most or all of the ecosystem processes on which *N. lithophila* depends are functioning properly at many or most of the occurrences of this species. Further research on the ecology and distribution of *N. lithophila* will help to develop effective approaches to management and conservation. Until a more complete picture of the distribution and ecology of this species is obtained, priorities lie with conserving the known occurrences, particularly those that support large population numbers, that are in excellent condition, and in which the surrounding landscape remains largely intact.

The ten occurrences documented on National Forest System lands include approximately 9,450 individuals plus others at occurrences where population size was not estimated. The largest known occurrence of *Neoparrya lithophila* is found at East Butte (EO 25), which occurs in part on the Rio Grande National Forest. Thus, a significant fraction (approximately one sixth) of the known population occurs on USFS lands of Region 2. The two most demonstrably imperiled occurrences (Methodist Mountain, Elliott 9066 and Bear Creek, Elliott 11675) are also found on National Forest System land. Thus, the USFS has many opportunities to improve the viability of this species through management actions.

Within the last 15,000 years, the climate in the southern Rocky Mountains has been both warmer and colder than it is at present. It is plausible to hypothesize

that the elevational limits of *Neoparrya lithophila* were different during these periods than they are today. Given the changes predicted in the global climate for the next 100 years, incorporation of higher elevation refugia for *N. lithophila* into preserve designs will help to ensure its long-term viability.

Tools and practices

Species and habitat inventory

Neoparrya lithophila is a relatively easy species for which to develop a search image. Searching for *N. lithophila* is also facilitated by the sparse vegetation and the relative ease of seeing the plants in a given habitat unit. Habitat units are usually discrete enough that they can be searched fairly thoroughly when visited by one to three field botanists. The greatest difficulty in conducting species inventories for *N. lithophila* is in accessing appropriate habitat, since it favors steep, rocky, inaccessible sites. *Neoparrya lithophila* is best sought from May through September when plants are in flower and fruit, but it can be sought at other snow-free times of the year as well.

Careful documentation and reporting is an important aspect of species inventory efforts. Important information to document includes locations that were visited, the date of the visit, the number and condition of individuals in the occurrence, habitat and associated species information, evidence of disease or predation, and any other pertinent observations. When a new occurrence of *Neoparrya lithophila* is located, an element occurrence report form for the appropriate state, accompanied by a copy of the appropriate portion of a 7.5- minute topographic map with the occurrence mapped, should be submitted to the state natural heritage program for the state in which the occurrence was found. Occurrence boundaries should be mapped as accurately as possible. Collection of voucher specimens (when appropriate) and submission to regional herbaria are also important for documenting newly identified occurrences. Regardless of population size, voucher photographs should be taken, and the location should be determined as exactly as possible. Obtaining precise location data using Global Positioning System technology can be a great help in relocating populations. Records should also document areas that were searched unsuccessfully.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine surveys of large areas, and could be highly effective for refining survey areas for *Neoparrya lithophila*. This approach has been very effective when used by Rondeau et al. (1998) and Kettler et al. (2000) to discover many occurrences of *N. lithophila*. It is most effective for species about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. Searching apparently suitable habitat in the vicinity of known occurrences is an effective starting point for species inventory work.

Recent searches by botanists in suitable habitat areas have found previously unknown populations in the last ten years, contributing the vast majority of our basic knowledge of the distribution and habitat for species. This approach is simple, inexpensive, and effective. Efforts to search for more occurrences and update records would contribute greatly to our knowledge of *Neoparrya lithophila*. Three element occurrence records in Conejos County (EO 18, 19, and 20) mention the presence of suitable habitat on nearby BLM lands that were not searched. National Forest System lands of the San Isabel and Rio Grande national forests are also high priorities for further inventory work.

Searches for *Neoparrya lithophila* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *N. lithophila* in given locations. This would be a valuable tool for guiding and focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003), and these methods are applicable to *N. lithophila* as well.

Population monitoring

A monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. Population monitoring would also be a useful means of detecting population trends under different management and human use scenarios. A monitoring program for *Neoparrya lithophila* targeting robust occurrences in both natural and unnatural settings could incorporate an investigation of human impacts such as recreation and grazing. Monitoring sites under a variety of land use scenarios will help to identify appropriate management practices for *N. lithophila* and will help to understand its population dynamics and structure.

Carron (1990) described methods used to monitor the Farisita Dike occurrence in 1990, 1991, 1992, and 1994; these methods are summarized as follows. A subset of the occurrence was selected randomly for monitoring, and 298 individual plants were marked using aluminum tags. The monitored occurrence was mapped to facilitate finding plants again in subsequent years. At each visit, all plants were reassessed. Reproductive effort was assessed by counting the number of flowering stems per plant. The number of seeds produced by the average flowering stem was apparently not determined, but this could be easily estimated by determining the number of seeds produced by a randomly selected subset of the flowering stems within the plot, as outlined in Carron (1990). This would permit the estimation of other demographic variables (seed set and fecundity) using the monitoring data. Size of each plant was assessed by measuring its canopy in two perpendicular dimensions. Using these data the area of the canopy of each plant can be determined using the formula for an ellipse ($\pi pAB/4$), and these data can be compared between years to assess growth rate and to infer age. Notes were also made when new seedlings were observed, and noteworthy observations were made pertaining to individuals (e.g., "plant sick," "plant dead," or "marker not found").

Elements of these methods plus others described in Elzinga et al. (1998) can be used to establish monitoring plots for *Neoparrya lithophila*. Lesica (1987) offers other suggestions for monitoring non-rhizomatous perennials such as *N. lithophila*. Carron (1990) and Schulz (personal communication 2002) suggest that gathering data every two years would be sufficient to monitor population trends in *N. lithophila*, since it is very slow-growing and long-lived. However, the first three consecutive years of data acquired at Farisita Dike suggest that monitoring every year may help to ensure that relevant variation in demographic variables is accounted for. Methods that would be useful for assessing the reproductive ecology of *N. lithophila* are described in Gaudeul and Till-Bottraud (2003).

Adding a photo point component to this work following recommendations offered in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) offers excellent instructions on establishing photo point monitoring plots.

Several methods of monumentation are recommended in Elzinga et al. (1998), depending on the site physiography and frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program. Monumentation will be somewhat challenging given the steep and sometimes unstable substrates where most populations of *Neoparrya lithophila* are found.

Estimating cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. Understanding environmental constraints on *Neoparrya lithophila* would facilitate the management of this species. Gathering data on edaphic characteristics (perhaps moisture, texture, and lysimetry, if possible) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species. Comparing lysimetry data between occupied and unoccupied habitat could help to explain why some apparently suitable sites are not occupied by *N. lithophila*.

If resources permit, all the known occurrences of *Neoparrya lithophila* could be monitored, doing half of them each year. Meaningful population trend data could probably be obtained from a subset of these occurrences. Selecting monitoring sites throughout the range of *N. lithophila* at a variety of substrates and elevations will provide a comprehensive picture of the population biology of this species.

Visiting occurrences in mid-summer while the plants are flowering would allow researchers to observe pollinator visitation. Suitable methods for monitoring pollinators are discussed in Kearns and Inouye (1993). However, measuring fecundity through the methods described above will require another visit later in the summer.

At present the priorities for Region 2 lie in basic survey work and establishing population baseline data since we still do not know the full distribution of *Neoparrya lithophila*. Gathering population size data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus, presence/absence monitoring is not recommended for *N. lithophila*.

To address the hypothetical metapopulation structure of *Neoparrya lithophila*, one approach might be to select highly suitable but unoccupied sites and attempt to observe colonization events. Ideal sites for this work could be found in the San Luis Hills,

where apparently suitable but unoccupied habitat has been reported. Given the life history characteristics of *N. lithophila*, it is possible that many years of data would be needed before meaningful inferences could be made about its metapopulation structure. Concurrent observations of local extinctions, which are fairly likely to occur in the smaller known populations, would also add to our understanding of the metapopulation structure of *N. lithophila*.

Habitat monitoring

Habitat monitoring of known occurrences would help alert managers of new impacts such as weed infestations and trampling. For *Neoparrya lithophila*, monitoring all the known occurrences with a visit every other year is feasible. This could be incorporated into the field forms used for the quantitative sampling regimen described above. Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998). Thus, habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. The use of photo points for habitat monitoring is described in Elzinga et al. (1998).

Beneficial management actions

Most comments regarding management of habitat for *Neoparrya lithophila* have recommended that "leaving it alone" is the best approach (Carron 1990, Rondeau et al. 1998, Kettler et al. 2000). Because most areas occupied by *N. lithophila* remain fairly pristine, it appears that current management of most occurrences favors their long-term viability.

The establishment of protected areas that would be managed for the conservation of *Neoparrya lithophila* is an important conservation strategy for this species. Because habitat units of *N. lithophila* are often relatively small and insular, designated protected areas will not typically need to be particularly large. Nine occurrences already benefit from protective land status designation (**Table 1**). However there remain high quality, robust occurrences on federal and private land, and the addition of these occurrences to the portfolio of protected occurrences would help assure the long-term protection of this species. The two largest known occurrences of *N. lithophila* are at East Butte (EO 25, with 7,000 to 8,000 individuals) and 660 Road (EO 6, with approximately 5,400 individuals). Protecting these occurrences in their entirety would help greatly to protect this species. Because both of these occurrences are also found in part on USFS lands, they may warrant consideration for research natural area designation. Both also occur in part on private land, where purchase or pursuit of conservation easements is worthy of consideration. Other locations of *N. lithophila* are also worthy of consideration of additional protective measures including Limekiln Creek Uplands (EO 16) and Hot Creek (EO 27).

There are several approaches that are likely to be effective in conserving unprotected occurrences, particularly if all of the available options are utilized. Bringing sites on private land into public ownership through land exchange or purchase could also protect occurrences from residential development. Similarly, consideration of land exchanges involving sites that are currently on public land would not benefit *Neoparrya lithophila*. Conservation easements and other land trust activities would be a useful conservation tool to protect the four occurrences on private land, as mentioned above for the East Butte and 660 Road occurrences. Purchasing conservation easements even on small properties may confer significant benefits to the conservation of *N. lithophila* since its occurrences and habitat are naturally insular and limited in size anyway. Purchase of land or conservation easements by county open space programs, such as that being developed by Fremont County, would also be a useful conservation tool. The conservation of *N. lithophila* would be an appropriate goal to include in county and city planning efforts. Management plans are needed for the BLM areas of critical environmental concern in which *N. lithophila* is found that address its conservation needs.

An additional level of protection for this species has been its designation as a sensitive species by both the USFS (which ended in 2003) and the BLM. New information on threats to occurrences on National Forest System lands suggests that *Neoparrya lithophila* may warrant reconsideration as a Region 2 sensitive species. Reinstatement of sensitive species status would empower USFS managers to be proactive on behalf of this species where the security and viability of this species are currently compromised by inappropriate use of habitat. Sensitive species status in Region 2 would also benefit *N. lithophila* by requiring consideration of the species in project areas containing suitable habitat. Because *N. lithophila* has now been found in New Mexico, it warrants consideration for addition to the sensitive species list for USFS Region 3 as well.

Management actions that limit recreational impacts are likely to confer significant benefits to this species. Discouraging the misuse of areas for off-

road vehicle recreation is needed at one occurrence (Elliott 9066, San Isabel National Forest) and probably others as well. The enforcement of off-road vehicle regulations and exclosures is challenging (Brekke personal communication 2004). Locating recreational infrastructure to ensure that it does not impact *Neoparrya lithophila* is an important consideration for its conservation.

Given the potential threats to *Neoparrya lithophila* and its habitat from exotic species, aggressive management of weeds in and near *N. lithophila* occurrences is a high priority for its conservation. Any management strategies that work to prevent the infestation of uninfested occurrences of *N. lithophila* are likely to confer the greatest benefits.

Although right-of-way management efforts have the potential to negatively impact some portions of occurrences of *Neoparrya lithophila*, these practices can be modified to mitigate impacts. Hand-pulling weeds where possible and appropriate probably has the least impact on occurrences of *N. lithophila*. Limiting the use of herbicides within occurrences of *N. lithophila* to direct application to target species will mitigate the loss of plants due to overspray and indiscriminate application.

Although direct impacts to *Neoparrya lithophila* from livestock are probably limited at most occurrences, management practices that reduce the impacts from grazing are likely to contribute greatly to the achievement of conservation goals for this species. Overgrazed rangelands are reported in the vicinity of numerous occurrences of *N. lithophila* (**Table 4**), where degradation of rangeland may exacerbate the threat of exotic species invasion. Research is needed to identify grazing regimes that are compatible with *N. lithophila*. Incorporating grazed and ungrazed areas into a monitoring protocol is one approach to determine the impacts from grazing. The use of exclosures where plants might be accessed by livestock would probably have little impact on available forage in most grazing allotments since the sites where *N. lithophila* is typically found are inaccessible and have very little to offer livestock. Fencing areas where cattle or horses could potentially graze is an inexpensive and effective way to protect those portions of occurrences that are accessible to grazers. This is probably also somewhat effective for reducing human impacts in heavily used areas. Some occurrences are found in sites where they are readily accessible to livestock, most notably at Bear Creek on the San Isabel National Forest (Elliott 11675). Observations at this occurrence show that preventing the installation of range improvements within *N. lithophila* occurrences is likely to confer significant benefits to the species. Maintaining livestock stocking rates at suitable levels will most likely prevent impacts to *N. lithophila* from grazing.

The establishment of a monitoring program would benefit *Neoparrya lithophila* by providing information on its population biology and threats that would help to develop better management protocols and conservation priorities. Studying its population genetics and autecology would have similar benefits from a management perspective, and would also provide valuable scientific data. Because occurrences of *N. lithophila* may remain to be documented, conducting pre-project surveys would verify that project impacts will not affect it.

Seed banking

No seeds or genetic material are currently in storage for *Neoparrya lithophila* at the National Center for Genetic Resource Preservation (Miller personal communication 2002). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2003). Collection of seeds for long-term storage will be useful if future restoration work is necessary. It appears that *N. lithophila* can be readily propagated by seed (Carpenter personal communication 2004).

Information Needs

Distribution

Given the high probability that more populations await discovery in Colorado and New Mexico, further survey work remains an important research need for *Neoparrya lithophila*. Recent work in Colorado in Rio Grande and Conejos counties by Kettler et al. (2000) suggest that 10 to 20 occurrences may remain to be discovered in the San Luis Valley, based on the prevalence of suitable habitat in the area that was not surveyed (Colorado Natural Heritage Program 2004). Hartman's discovery of the species in New Mexico also underscores the fact that there remains much to be learned regarding the distribution of this species. Further targeted inventory work would permit an accurate assessment rangewide of conservation priorities for this species.

Lifecycle, habitat, and population trend

Very little is known about the population ecology of *Neoparrya lithophila* and closely related members of the genus *Aletes*. There has been no rigorous study of the life cycle and autecology of any of these species from which inferences could be drawn regarding *N. lithophila*. Investigating habitat variables to which *N. lithophila* may be particularly responsive is important for its proper stewardship and for understanding the reasons for its rarity. For example, investigating is ecophysiological responses to variation in soil chemistry may help to determine the breadth of its habitat amplitude and critical ecological variables.

Extensive survey work in Rio Grande, Conejos, and Saguache counties by the Colorado Natural Heritage Program (Rondeau et al. 1998, Kettler et al. 2000) and the floristic inventory work of Elliott (2000) have yielded valuable information on the habitat for this species. These data are largely qualitative in nature but include detailed descriptions of all the known locations and relevant natural history observations. In the San Luis Hills there is much apparently suitable habitat that is not occupied. Thus, information on the pollination ecology, dispersal ability, seed germination, and physiological ecology of this species would help greatly in prioritizing further areas for searching. This would also facilitate effective conservation stewardship of this species.

Response to change

There have been no cases documented in which habitat for *Neoparrya lithophila* was significantly altered by natural or anthropogenic processes. The specific responses of *N. lithophila* to disturbance and succession are not clear and warrant further investigation. There has been no specific research on *N. lithophila* addressing these issues. The effects of exotic species such as *Bromus tectorum*, *Cirsium arvense*, *Salsola tragus*, *Kochia scoparia*, and *Hyoscyamus niger* on the viability of *N. lithophila* occurrences have not been investigated. Given its slow growth rate, it stands to reason that *N. lithophila* may recover slowly to impacts that reduced its population size. However, the presence of a large seed bank might buffer occurrences from such impacts. Beyond broad inferences such as this, it is difficult to ascertain how *N. lithophila* would respond to change, given the current paucity of ecological information.

Metapopulation dynamics

There has been little work from which meaningful inferences can be drawn regarding the metapopulation structure and dynamics of *Neoparrya lithophila*. The genetic study of *Aletes humilis* by Linhart and Premoli (1993) infers that at some point in that species' history populations had some degree of genetic connectivity. However, the relationship of these findings to past or present metapopulation dynamics is unknown. It is likely that metapopulation dynamics are of little importance for the long-term viability of *N. lithophila* because it is found primarily in relatively persistent habitats.

Demography

The monitoring of the Farisita Dike population has provided some basic insights into the demography of *Neoparrya lithophila*. Continuation of monitoring efforts at this occurrence and others would contribute further to our understanding of its population structure. If seeds could still be found that were deposited in 1991 by West (1991), testing their viability would provide valuable information on the longevity of seeds and the seed bank. Research is needed to determine the genetic structure and diversity within and among populations, and the minimum viable population size. Reproductive output, recruitment, longevity, and other demographic parameters are not known. Our knowledge of the distribution of the species is good but may still be incomplete. Therefore much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques. Short-term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002). However, the value of demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

Monitoring of the Farisita Dike occurrence generated potentially useful data on population trends. Using methodology similar to that described in Carron (1990) in other populations could provide meaningful trend data with limited effort. Please also see the Population Monitoring section under Tools and Practices in this document for an overview of applicable methodology. Selection of monitoring sites from a

variety of physiognomic and geological settings and land use scenarios will be necessary to monitor trend at the population level.

Restoration methods

Because no attempts have been made to restore occurrences of *Neoparrya lithophila* or members of the genus *Aletes*, there is no applied research from which to draw in developing a potential restoration program. Although no scientific data are available on the feasibility of propagating this species, it has been successfully grown in a flower bed by Carpenter (personal communication 2002). He collected seeds from the Farisita Dike occurrence, and they grew readily in his garden in typical garden soil. This suggests that plants could be propagated in a greenhouse environment. However, such plants would probably be very difficult to transfer successfully into a natural or quasi-natural (restored) setting because of the xeric conditions and the natural complexity of the microsites it often inhabits.

Research priorities for Region 2

The most obvious research priority for *Neoparrya lithophila* is a better understanding of its range, distribution, and habitat affinities. Other research needs are cited by Rondeau et al. (1998), many of which apply to *Neoparrya*, *Aletes*, and related taxa in the Apiaceae. These include research on floral biology, dispersal, predators, germination requirements, and longevity. Identifying the pollinators for *N. lithophila* will help to identify appropriate conservation strategies, and will also contribute valuable scientific data on the floral biology of this species. Understanding the physiological ecology of *N. lithophila* will help to determine why apparently suitable habitat in the San Luis Hills and other locations is not occupied. Investigations of the genetic structure of occurrences will help to understand the degree of genetic isolation and diversity of occurrences of *N. lithophila*. This will be important for stewardship and in setting conservation priorities. Investigating the population biology of *N. lithophila* will also yield valuable data such as recruitment rate and annual variation in recruitment. Studies of the autecology of *N. lithophila* will begin to reveal the interspecific relationships that affect it, and will help managers to predict the effects of human disturbance, weed invasion, and climate change.

Additional research and data resources

Monitoring data on the Farisita Dike occurrence of *Neoparrya lithophila* that had been gathered by The Nature Conservancy between 1990 and 1992 (the 1994 data could not be found) were obtained and analyzed, and the results were incorporated into this report in relevant sections. These data are available through Terri Schulz with The Nature Conservancy. Jeanette Flaig, a master's student at the University of Wyoming, is conducting a floristic inventory of the eastern San Juan Mountains. Her work is not complete but may continue to identify new discoveries of occurrences of this species.

Definitions

50/500 rule — A generalized rule stating that isolated populations need a genetically effective population of about 50 individuals for short term persistence and a genetically effective population of about 500 for long-term survival (Soulé 1980).

Cladistics — A classification system that expresses the branching relationships between species through a phylogenetic tree with ancestral forms at the bottom and recently diverged ones at the top (Art 1993).

CSR (Competive/Stress-tolerant/Ruderal) model — A model developed by J.P. Grime in 1977 in which plants are characterized as competitive, stress-tolerant, or ruderal, based on their allocation of resources. Competitive species allocate resources primarily to growth; stress-tolerant species allocate resources primarily to maintenance; and ruderal species allocate resources primarily to reproduction. A suite of other adaptive patterns also characterizes species under this model. Some species show characteristics of more than one strategy (Barbour et al. 1987).

Dichogamy — The maturation of male and female organs of a flower at different times (Hartman personal communication 2002).

Ecotype — The morphological expression of a unique genotype that is adapted to particular habitat attributes (after Allaby 1998).

Exserted — Projecting beyond the surrounding parts, as in stamens protruding from the corolla of *Neoparrya lithophila* (Harris and Harris 1999).

Iteroparous — Producing offspring in a series of separate events, occurring two or more times during the lifespan of an organism (Art 1993).

Monophyletic — Applied to a group of species that share a common ancestry (Allaby 1998).

Protogynous — Flowers in which the styles are well exserted several days before the anthers are evident. Thus, although a flower may be self fertile, it is functionally female until the anthers dehisce, and will tend to outcross. The timing of the maturation of the male and female organs in the flowers is usually synchronized throughout a plant so that pollen from other flowers on the same plant does not tend to reach the stigmas (Hartman personal communication 2002).

Synapomorphy — A shared derived character state (Judd et al. 2002).

Imperilment Ranks used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe.

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

G/S1	Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G/S2	Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).
G/S4	Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery.
G/S5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GX	Presumed extinct.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but not verified for an extended period, usually.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not permanent residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected.
SA	Accidental in the state or province.
SR	Reported to occur in the state or province, but unverified.
S?	Unranked. Some evidence that the species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

References

Allaby, M. 1998. A Dictionary of Plant Sciences. Oxford University Press, New York, NY.

Art, H.W. 1993. The Dictionary of Ecology and Environmental Science. Henry Holt and Company, New York, NY.

Bailey, R.G. 1995. Description of the Ecoregions of the United States. Second edition. Miscellaneous Publication Number 1391. USDA Forest Service, Washington, D.C.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA.

Baskin, C.C. and J.M. Baskin. 2001. Seeds- Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press. San Diego, CA.

Bell, C.R. 1971. Breeding systems and floral biology of the Umbelliferae, or evidence for specialization in unspecialized flowers. *In*: V.H. Heywood, editor. The Biology and Chemistry of the Umbelliferae. Botanical Journal of the Linnean Society 64, Supplement 1:93-107.

Brekke, E. 2004. Personal communication with Bureau of Land Management Wildlife Biologist regarding management of BLM lands with respect to off-road vehicle use.

Bureau of Land Management. 2000. Colorado BLM State Director's Sensitive Species List. Accessed via the Internet at http://www.co.blm.gov/botany/sens_species.htm.

Burrows, G.E. and R.J. Tyrl. 2001. Toxic Plants of North America. Iowa State University Press, Ames, IA.

Carpenter, A. 1992. *Neoparrya lithophila* Monitoring at Farisita Dike. Monitoring data from 1990, 1991, and 1992 provided by T. Schulz, The Nature Conservancy.

Carpenter, A. 2002. Personal communication with Botanist/Consultant regarding *Neoparrya lithophila*.

Carpenter, A. 2004. Personal communication with Botanist/Consultant regarding *Neoparrya lithophila*.

Carron, J.C. 1990. Element Stewardship Abstract for *Neoparrya lithophila* (Rock-Loving Neoparrya). Unpublished report prepared by The Nature Conservancy.

Carsey, K. 1996. Establishment Record for the Spring Branch Research Natural Area. San Juan-Rio Grande National Forests, Rio Grande County, Colorado. Produced for the USDA Forest Service Region 2.

Caswell, H. 2001. Matrix Population Models. Second Edition. Sinauer Associates, Inc., Sunderland, MA.

Center for Plant Conservation. 2003. National Collection of Endangered Plants. Accessed via the Internet at: http://ridgwaydb.mobot.org/cpcweb/CPC_NCList_Find.asp. Missouri Botanical Garden.

Chronic, H. 1980. Roadside Geology of Colorado. Mountain Press Publishing Co., Missoula, MT.

Colorado Native Plant Society. 1997. Rare plants of Colorado. Second edition. Falcon Press, Helena, MT.

Colorado Natural Heritage Program. 2004. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, CO.

Colorado State Parks. 2004. Colorado Natural Areas Program. Accessed via the Internet at: http://parks.state.co.us/cnap/NAinfo.htm.

Crawford, D.J. and R.L. Hartman. 1972. Chromosome numbers and taxonomic notes for Rocky Mountain Umbelliferae. American Journal of Botany 59(4):386-392.

Downie, S.R., R.L. Hartman, F.J. Sun, and D.S. Katz-Downie. 2002. Polyphyly of the spring-parsleys (Cymopterus): molecular and morphological evidence suggests complex relationships among the perennial endemic genera of western North American Apiaceae. Canadian Journal of Botany 80:1295-1324.

Elliott, B. 2000. A Vascular Flora of South-Central Colorado. M.S. Thesis submitted to the Department of Botany, University of Wyoming, Laramie, WY.

Elliott, B. 2004. Personal communication with USDA Forest Service Botanist for the San Isabel National Forest regarding *Neoparrya lithophila*.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1.

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species. Wyoming Natural Diversity Database, Laramie, WY.

Flaig, J. 2004. Personal communication with Master's student at the University of Wyoming/Rocky Mountain Herbarium regarding *Neoparrya lithophila*.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Reviews of Ecological Systems 29:207-231.

Gaudeul, M. and I. Till-Bottraud. 2003. Low selfing in a mass-flowering, endangered perennial, *Eryngium alpinum* L. (Apiaceae). American Journal of Botany 90 (5):716-723.

Giorgi, F., L.O. Mearns, C. Shields, and L. McDaniel. 1998. Regional nested model simulations of present day and 2 x CO_2 climate over the central plains of the U.S. Climatic Change 40:457-493.

Grant, V. 1949. Pollination systems as isolating mechanisms in Angiosperms. Evolution 3:82-97.

Grime, J.P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. Second edition. John Wiley & Sons, Chichester, West Sussex, England.

Hall, F.C. 2002. Photo Point Monitoring Handbook- Parts A and B. General Technical Report PNW-GTR 526. USDA Forest Service Pacific Northwest Research Station, Portland, OR.

Hamrick, J.L. and M.J.W. Godt. 1990. Allozyme diversity in plant species. *In*: A.H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, editors. Population Genetics and Germplasm Resources in Crop Improvement 44-64. Sinauer Associates, Inc., Sunderland, MA.

Harris, J.G. and M.W. Harris. 1999. Plant Identification Terminology- an Illustrated Glossary. Spring Lake Publishing, Spring Lake, UT.

Hartman, R.L. 1984. *Neoparrya lithophila* Math. (Apiaceae): is it truly rare? Unpublished report.

Hartman, R.L. 2002. Personal communication with expert on the Apiaceae regarding *Neoparrya lithophila*.

Hartman, R.L. 2004. Personal communication with expert on the Apiaceae regarding *Neoparrya lithophila*.

Heywood, V.H. 1993. Flowering Plants of the World. Oxford University Press, New York, NY.

Holt, E. 2002. Vascular Flora of the Sawatch, West Mosquito, and West Gore Ranges and Castle Peak Area, Colorado. M.S. Thesis submitted to the Department of Botany, University of Wyoming. Laramie, WY.

Inoue, K. and T. Kawahara. 1990. Allozyme differentiation and genetic structure in island and mainland Japanese populations of *Campanula punctata* (Campanulaceae). American Journal of Botany 77:1440-1448.

Johnston, B. 2002. Personal communication with USDA Forest Service Botanist regarding *Neoparrya lithophila*.

Judd, W.S., C.S. Campbell, E.A. Kellogg, P.F. Stevens, and M.J. Donoghue. 2002. Plant Systematics: a Phylogenetic Approach. Second edition. Sinauer Associates, Inc., Sunderland, MA.

Karron, J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in* D. Falk and K. Holsinger, editors. Genetics and Conservation of Rare Plants. Oxford Press, Oxford, U.K.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. *In*: J.T. Kartesz and C.A. Meacham. Synthesis of the North American Flora [computer program]. Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Kearns, C.A. and D.W. Inouye. 1993. Techniques for Pollination Biologists. University Press of Colorado, Niwot, CO.

Kettler, S., J. Rocchio, R. Schorr, and J. Burt. 2000. Biological Inventory of Rio Grande and Conejos Counties, Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Klinka, K., V.J. Krajina, A. Ceska, and A.M. Scagel. 1989. Indicator Plants of Coastal British Columbia. University of British Columbia Press, Vancouver, BC, Canada.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2):65-8.

Lindborg, R. and J. Ehrlén. 2002. Evaluating the extinction risk of a perennial herb: demographic data versus historical records. Conservation Biology 16:683-690.

Lindsey, A.H. and C.R. Bell. 1985. Reproductive biology of Apiaceae. II. Cryptic specialization and floral evolution in *Thaspium* and *Zizia*. American Journal of Botany 72:231-247.

Linhart, Y.B. and A.C. Premoli. 1993. Genetic variation in *Aletes acaulis* and its relative, the narrow endemic *A. humilis* (Apiaceae). American Journal of Botany 80:598-605.

Manabe, S. and R.T. Wetherald. 1986. Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide. Science 232:626-628.

Mathias, M.E. 1929. Studies in the Umbelliferae. II. Annals of the Missouri Botanical Garden 16:393-396+398.

Miller, A. 2002. Personal communication with National Center for Genetic Resource Preservation Botanist regarding *Neoparrya lithophila*.

Moore, D.M. 1971. Chromosome studies in the Umbelliferae. *In*: V.H. Heywood, editor. The Biology and Chemistry of the Umbelliferae. Botanical Journal of the Linnaean Society 64, Supplement 1:233-255.

NatureServe Explorer. 2001. NatureServe Explorer: an online encyclopedia of life [web application].

Neely, E. 1986. Farisita Dike, Colorado. Preserve Design. Prepared for The Nature Conservancy, Colorado Field Office.

Neely, E., P. Comer, C. Moritz, M. Lammert, R. Rondeau, C. Pague, G. Bell, H. Copeland, J. Humke, S. Spackman, T. Schulz, D. Theobald, and L. Valutis. 2001. Southern Rocky Mountains: An Ecoregional Assessment and Conservation Blueprint. Prepared by the Nature Conservancy with support from the USDA Forest Service, Rocky Mountain Region, Colorado Division of Wildlife, and Bureau of Land Management.

O'Kane, S.L. 1986. Floristic Reconnaissance of the San Luis Valley. Unpublished prepared for The Nature Conservancy.

O'Kane, S.L., Jr., D.H. Wilken, and R.L. Hartman. 1988. Noteworthy Collections of *Aralia racemosa*, *Astragalus humillimus*, *A. sericoleucus*, *Atriplex pleiantha*, *Crepis capillaris*, *Cryptantha weberi*, *Dithyrea wizlizenii*, *Ipomopsis congesta* ssp. *crebrifolia*, *Lomatium bicolor*, *Mentzelia densa*, *Neoparrya lithophila*, and *Rumex verticillatus*. Madrono 35 (1):72-74.

Parenti, R.L., Jr., A.F. Robinson, and J. Kagan. 1993. Bradshaw's Lomatium Recovery Plan. Unpublished report prepared for the U.S. Fish and Wildlife Service, Portland, OR.

Patton, G., A. Kratz, and P. McDonald. 2002. R2 Individual Species Recommendations for *Neoparrya lithophila* (Revised by A. Kratz and N. Warren). Accessed via the Internet at: http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml.

Peterson, S.J., B.C. Johnston, and W. Harmon. 1983. USFWS status report for *Neoparrya lithophila*. Denver, CO, Colorado Natural Inventory Program.

Poe, J. 2004. Personal communication with Rio Grande National Forest Range Specialist regarding grazing allotments on the Rio Grande National Forest.

Powell, J. 2003. Personal communication with Colorado Department of Transportation threatened and endangered species specialist regarding management of roadside plant populations.

Rondeau, R., D. Sarr, M.B. Wunder, P.M. Pineda, and G.M. Kittel. 1998. Saguache County, Closed Basin Biological Inventory Volume I: A Natural Heritage Assessment Final Report. Colorado Natural Heritage Program.

Ryke, N., D. Winters, L. McMartin, and S. Vest. 1994. Threatened, Endangered, and Sensitive Species of the Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands. USDA Forest Service.

Schulz, T. 2002. Personal communication with Conservation Ecologist with The Nature Conservancy regarding *Neoparrya lithophila*.

Schulz, T. 2004. Personal communication with Conservation Ecologist with The Nature Conservancy regarding *Neoparrya lithophila*.

Scott, M.J., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson. 2002. Predicting Species Occurrences- Issues of Accuracy and Scale. Island Press, Washington, D.C.

Soulé, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 *in* M.E. Soulé and B.A. Wilcox, Editors. Conservation Biology: an Evolutionary Perspective. Sinauer Associates, Inc., Sunderland, MA.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, the USDA Forest Service and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program.

Theobald, W.L., C.C. Tseng, and M.E. Mathias. 1964. A revision of *Aletes* and *Neoparrya* (Umbelliferae). Brittonia 16:296-315.

Tweto, O. 1979. Geologic Map of Colorado. Compiled by the U.S. Geological Survey with technical assistance by the Colorado Geological Survey.

USDA Forest Service Region 2. 1993. Regional Forester's Sensitive Species List. USDA Forest Service Region 2, Lakewood, CO.

USDA Forest Service Region 2. 2003. Forest Service Manual Rocky Mountain Region. Chapter 2670. Threatened, Endangered, and Sensitive Plants and Animals. USDA Forest Service Region 2, Lakewood, CO.

USDA Natural Resources Conservation Service. 2002. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490.

U.S. Environmental Protection Agency. 1997. Climate Change and Colorado. EPA 230-F-97-008f. Office of Policy, Planning, and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

Webb, J.B. 1996. Rio Grande National Forest Grazing Allotment Closure Record of Decision. Accessed via the Internet at http://www.fs.fed.us/r2/riogrande/planning/planning.htm.

Weber, W.A. 1958. Rediscovery of the genus *Neoparrya* Mathias (Umbelliferae). Rhodora 60:265-271.

Weber, WA. 1984. New names and combinations, principally in the Rocky Mountain flora--IV. Phytologia 55:1-11.

West, K. 1991. Seed Germination Experiment. Memo to The Nature Conservancy's *Neoparrya lithophila* monitoring file dated December 11, 1991. Provided by T. Schulz, The Nature Conservancy.

White, M. 2004. Personal communication with San Isabel National Forest Range Specialist regarding grazing allotments on the San Isabel National Forest.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press, Chapel Hill, NC.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audio-tape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326 W, Whitten Building, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.